STUDENT GUIDE

FOR

ADVANCED FIRST-TERM AVIONICS COURSE

CLASS A1

C-100-2010

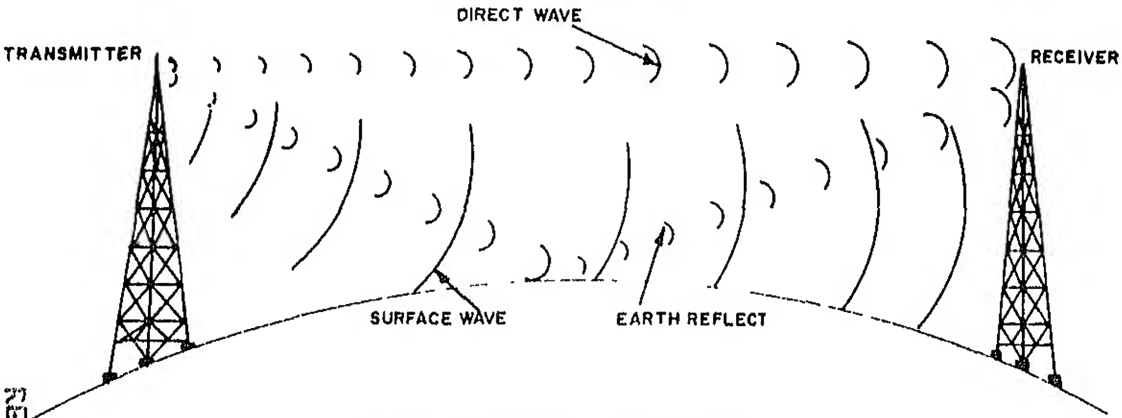

FIGURE I - COMPONENTS OF GROUND WAVE

UNIT IV

CNTT-M1701

PREPARED BY

NAVAL AIR TECHNICAL TRAINING CENTER

NAVAL AIR STATION MEMPHIS

MILLINGTON TENNESSEE

PREPARED FOR

CHIEF OF NAVAL TECHNIAL TRAINING

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FOREWORD

The purpose of this Student's Guide is to provide you with the information sheets, notetaking outlines, drawings, and charts for your use during each lesson of Unit IV. The proper use of this Student's Guide will aid you in learning and retaining the information given in each lesson. There is a drawing supplied for each transparency used in the lesson, so that you can take notes on a drawing exactly the same as the transparency the instructor is using. The notetaking outline supplied for each lesson is meant as a GENERAL guideline. It is NOT necessary to have each blank filled in, as sometimes notes will be written on a drawing, chart, or schematic. All this information will aid you in analyzing the operation of receivers and transceivers.

The table of contents lists the page numbers for each information sheet, notetaking sheet, and chart.

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SAFETY NOTICE

As an avionics technician, you will be required to perform safe and efficient maintenance on various types of electronic equipment. Not only your life, but the lives of many others will depend on your being safety conscious at all times. It is the responsibility of all Navy and Marine Corps personnel to prevent accidents. This can be done if everyone develops good safety habits and observes all precautions when performing maintenance of any type.

HOW TO USE THIS STUDENT'S GUIDE

This Student's Guide has been prepared for you to use during each lecture of Unit IV of the Advanced First-Term Avionics (A1) Course.

Use the notetaking outlines, drawings, and charts to make your notes. You may also take notes directly on your schematics.

This volume contains the following:

1. The terminal objectives for Unit IV.

2. The major enabling objectives for Unit IV.

3. Notetaking sheets, drawings, and charts necessary for each classroom lesson.

4. Assignment and information sheets to enhance your understanding.

5. Class schedule for Unit IV.

GOOD LUCK! Learn all you can!

UNIT IV CLASS SCHEDULE

Unit IV is two weeks long and starts in the middle of the fifth day of the 6th week. The periods run from 237 through 316 with the last period finishing half way through the fifth day of the 8th week.

The schedule is as follows:

TOPIC NO.	TYPE	PERIOD	TOPIC
SIXTH WEEK			
Fifth Day			
	Class	233	Unit Test: Written Examination
		234	
		235	
		236	
4.1	Class	237	Duty Preference Cards
		238	
4.2	Class	239	Radio Frequency Power Amplifiers
		240	
SEVENTH WEEK			
First Day			
4.2	Class	241	Radio Frequency Power Amplifiers
		242	
		243	
		244	
		245	
		246	
4.3	Class	247	Amplitude-Modulated Transmitters
		248	
Second Day			
4.3	Class	249	Amplitude-Modulated Transmitters
		250	
		251	
4.4	Class	252	Amplitude-Modulated Receivers
		253	
		254	
4.5	Class	255	Introduction to UHF
		256	

TOPIC NO.	TYPE	PERIOD	TOPIC
Third Day			
4.6	Class	257	UHF Transceiver Block Diagram
		258	
		259	
		260	
		261	
4.7	Class	262	UHF Transmitter Circuit Analysis
		263	
		264	
Fourth Day			
4.7	Class	265	UHF Transmitter Circuit Analysis
		266	
		267	
4.8	Class	268	UHF Receiver Circuit Analysis
		269	
		270	
		271	
		272	
Fifth Day			
4.9	Class	273	Guard Receivers
		274	
4.10	Class	275	Automatic Radio Direction Finding (ARDF)
		276	
		277	
	Class	278	Unit Test: Written Examination
		279	
		280	

EIGHTH WEEK

TOPIC NO.	TYPE	PERIOD	TOPIC
First Day			
4.11	Class	281	Basic FM Theory
		282	
		283	
		284	
4.12	Class	285	Single-Sideband Principles
		286	
		287	
		288	

TOPIC NO.	TYPE	PERIOD	TOPIC
Second Day			
4.12	Class	289	Single-Sideband Principles
		290	
		291	
4.13	Class	292	Single-Sideband Special Circuits
		293	
		294	
		295	
		296	
Third Day			
4.14	Class	297	Radio Wave Propagation
		298	
		299	
4.15	Class	300	Transmission Line Theory
		301	
		302	
		303	
		304	
Fourth Day			
4.15	Class	305	Transmission Line Theory
4.16	Class	306	Uses of Transmission Lines
		307	
		308	
		309	
4.17	Class	310	Theory of Antennas
		311	
		312	
Fifth Day			
		313	Unit Test: Written Examination
		314	
		315	
		316	
5.1	Class	317	Introduction to Digital Computers
		318	
5.2	Class	319	Mathematics of Digital Computers
		320	

UNIT IV HOMEWORK SCHEDULE

All of the assignment sheets listed below shall be turned in when due. Each assignment sheet will be checked by an instructor for completeness and correctness. Failure to turn in an assignment sheet could result in disciplinary action.

Assignment Sheet	Period Due
4.2.1A	249
4.3.1A	257
4.4.1A	257
4.5.1A	257
4.6.1A	265
4.7.1A	273
4.8.1A	273
4.9.1A	281
4.10.1A	281
4.11.1A	289
4.12.1A	297
4.13.1A	297
4.14.1A	305
4.15.1A	313
4.16.1A	313
4.17.1A	313

UNIT LEARNING OBJECTIVES

TERMINAL OBJECTIVE

8.0. ANALYZE the operation of a typical amplitude-modulated transceiver by tracing signal paths through communications circuits, using given block and schematic diagram. Performance will be measured by a written multiple-choice examination.

ENABLING OBJECTIVES

8.1. ANALYZE the operation of a given typical amplitude-modulated transceiver block diagram by TRACING signal paths through the block diagram. Performance will be measured by a written multiple-choice examination.

8.2. ANALYZE the operation of a given typical amplitude-modulated transceiver schematic by TRACING signal paths through communications circuits. Performance will be measured by a written multiple-choice examination.

TERMNAL OBJECTIVE

9.0. ANALYZE the operation of a typical frequency-modulated transceiver by TRACING signal paths through given communications circuits, using block diagrams and excerpts of schematic diagrams. Performance will be measured by a written multiple-choice examination.

ENABLING OBJECTIVES

9.1. ANALYZE the operation of a given typical frequency-modulated transceiver block diagram by TRACING signal paths through the block diagram. Performance will be measured by a written multiple-choice examination.

9.2. ANALYZE the operation of a typical frequency-modulated transceiver by TRACING signal paths through given communications circuits. Performance will be measured by a written multiple-choice examination.

TERMINAL OBJECTIVE

10.0. Mathematically ANALYZE the operating characteristics of given transmission lines and antennas by SOLVING problems in terms of voltage, impedance, current, power, standing waves, and wave propagation. Response will be in accordance with Electronic Circuit Analysis, Vol. II, NAVAIR 00-80-T-79. Performance will be measured by a written multiple-choice examination.

ENABLING OBJECTIVES

10.1. Mathematically ANALYZE the operating characteristics of given transmission lines by SOLVING problems in terms of voltage, impedance, current, power, standing waves, and wave propagation. Response will be in accordance with Electronic Circuit Analysis, Vol. I, NAVAIR 00-80-T-79. Performance will be measured by a written multiple-choice examination.

10.2. Mathematically ANALYZE the operating characteristics of given antennas by SOLVING problems in terms of voltage, impedance, current, power, standing waves, and wave propagation. Response will be in accordance with Electronic Circuit Analysis, Vol. I, NAVAIR 00-80-T-79. Performance will be measured by a written multiple-choice examination.

INFORMATION SHEET 4.1.1I

DUTY PREFERENCE CARDS

INTRODUCTION

Your duty preference card is the single most important item that the detailer has when considering what your duty preference is. This information sheet is provided for your use as an aid to help you correctly fill out your duty preference card so that the detailer will have an accurate picture of what duty you desire.

REFERENCE

1. TRANSMAN

INFORMATION

SHORE DUTY--When choosing a shore priority, keep in mind that the Navy has a policy of "All sailors aboard ship and all ships at sea", which means the detailer will place you in a sea duty billet for your initial assignment if deemed necessary.

Choose two shore locations. AT's may choose any on the list. AQ's choose only those marked with a Q. AX's choose those marked with a X.

YOO Anywhere west of the Miss. Rvr. Q X
ZOO Anywhere east of the Miss. Rvr. Q X
COO Anywhere Continental U.S. Q X
KCA Anywhere California Q X
KCK CA China Lake Q
LLF CA Lemoore Q
LMO CA Moffett Field X
KSD CA San Diego (includes N.I. & Mirmar) Q X
GJK FL Jacksonville Q X
GFC FL Cecil Feild Q X
GKE FL Key West Q
GPE FL Pensacola
KPS CA Point Mugu
CBS MN Brunswick X
PPA MD Patuxent Rvr Q X
GMG MS Meridian
LFA NV Fallon Q
GME TN Memphis X
HBV TX Beeville
HCC TX Corpus Christi
HKI TX Kingsville
FNO VA Norfolk X
FOA VA Oceana Q
MWI WA Whidby Island Q

NOTE: The location you choose must match the type duty!!! If not, you are wasting your time and the detailer's, who will be perturbed at you.

OVERSEA DUTY--When making your overseas duty choices, consider that most overseas duty is shore duty for rotation purposes. This means that when your tour is completed you will be reassigned to sea duty.

Overseas duty that is considered sea duty will be marked by having the rate designations within ()'s.

Overseas duty that is considered shore will not have the ()'s.

Rate designations are AT's--T, AX's--X, and AQ's--Q.

Choose two from the following list, remembering that location must match type.

ADA AL Adak (T X)
AZO Azores (T X)
BER Bermuda T X
CUB Cuba (T)
DGO Diego Garcia (T X)
EUR Anywhere Europe (T X)
GUM Guam T X (VQ T)
OTH Hawaii T X (VP T X)

ICE Iceland (T X)
JAA Japan (T Q X)
SOO Anywhere Pacific (T Q X)
PHI Philippine Islands T Q X
PUR Puerto Rico T X
SIC Sicily (T X)
SRT Sp. Rota T X (VQ T)
OKI Okinawa (T X)

SEA DUTY

In choosing your sea duty preferences, bear in mind that this is your best chance at getting your choice. Make you choices VERY CAREFULLY because where you go for this initial sea duty assignment will largely determine your future training and future duty assignments. The detailer tries for geographical location mainly.

Choose two from the list below, remembering that the type of duty must match the location.

YOO Anywhere West of the MS Rvr. T Q X
ZOO Anywhere East of the MS Rvr. T Q X
OOO Anywhere U.S.A. T Q X
KCA Anywhere California T Q X
LAL CA Alameda T Q
LLF CA Lemoore T Q
LMO CA Moffett Field T X
KSD CA San Diego T Q X
GFL FL Anywhere T Q X
GJK FL Jacksonville T Q X

GKE FL Key West T
GMY FL Mayport T Q X
GPE FL Pensacola (CV only) T
CBS MN Brunswick T X
FVA VA Anywhere T Q X
FNO VA Norfolk T Q X
FOA VA Oceana T Q
MWI WA Whidby Island T Q
GFC FL Cecil Feild T Q X

TYPE DUTY LIST

The type duty blocks are used for shore, sea and overseas duties. For ships and squadrons, use their respective designations (VF, VR, CV, etc.). NAS is used for shore billets.

When asking for shore duty you have the option of asking for a type squadron, which means you are asking to be assigned with a FRAMP Training Squadron. These squadrons are located with their fleet counterprts.

SHORE DUTY:

The following is a list of type duties and the eligible rates.

NOTE: Aircrew choose only those types with a # (AX aircrew VP only).

VX--Air Test and Development Squadron--Most of the experimental work in these squadrons is done under civilian contract. The military only maintains the aircraft.

Locations--Point Mugu, CA VX-4 — Rates AT, AQ
China Lake CA VX-5 — AT, AQ
Patuxent River MD VX-1 — AT, AX

VT--Training Squadron--Designed for pilot training with some short periods aboard carriers for carrier qualifications.

Locations--Pensacola FL
Meridian MS
Beeville TX
Kingsville TX
Corpus Christi TX — Rates AT

VR--Logistic Support (transport) Squadron--Designed for cargo and mail. These are relatively small units and are a little more difficult to get.

Locations--North Island CA VRC-30
Norfolk VA VRC-40 — Rates AT

VC--Composite Squadron--Used for target towing and launching. These are small units also.

Locations--San Diego CA
Roosevelt Roads P.R. — Rates AT

SEA DUTY:

#VP--Antisubmarine Warfare
Rates- AT, AX
A/C P-3 Orion
Locations--Barbers Point HI (5)
Brunswick MN (5)
Jacksonville FL (8)
Moffett Field CA (8)

VS--Shipboard ASW
Rates- AT, AX
A/C S-3 Viking
Locations--North Island CA (6)
Cecil Field FL (6)

HS--Helicopter ASW; SAR Carrier Based
Rates AT, AX
A/C H-3
Locations--North Island CA (6)
Jacksonville FL (7)

HSL--LAMPS Helos Destroyer Based
Rates AT, AX
A/C H-2, H-60
Locations--San Diego CA (4)
Norfolk VA (3)
Barbers Point HI (1)
Mayport FL (1)

VA--Light Attack
Rates AT, AQ
A/C A-7 Corsair II
F/A-18 Hornet
Locations--Lemoore CA (13)
Cecil Field FL (12)
Key West FL (1)
Yokosuka Japan (1)

VA--Medium Attack
Rates AT, AQ
A/C A-6 Intruder
Locations--Whidbey Island WA (6)
Oceana VA (7)
Yokosuka Japan (1)

VF--Fighter
Rates AT, AQ
A/C F-4 Phantom F-14 Tomcat
Locatons--Miramar CA (12)
Oceana VA (15)
Yokosuka Japan (2)

#VAW--Early Warning; Carrier Based
Rates AT
A/C E-2 Hawkeye
Locations--Miramar CA (6)
Norfolk VA (8)
Yokosuka Japan (1)

VAQ--Electronic Warfare; Carrier Based
Rates AT, AQ
A/C EA-6 Prowler
Locations--Whidby Island WA (10)
Key West FL VAQ-33 (1)
Point Mugu CA VAQ-34 (1)

#VQ--Special Electronics
Rates AT, AQ, AX
Locations--Guam VQ-1
Rota Spain VQ-2
Pax River MD VQ-4 (shore)
Barbers Point HI VQ-3

VRC--Carrier Logistic Support
Rates AT
Locations--Norfolk VA
Cubi Point P.I

HC--Helicopter Composite-Vertical replenishment
Rates AT
A/C H-46, H-53
Locations--North Island CA (4)
Norfolk VA (1)
Signonella Sicily (1)
Pensacola FL (1)

CARRIERS and their home ports.

East Coast

CV-59 Forrestal- Mayport FL
CV-60 Saratoga- Mayport FL
CV-62 Independence- Norfolk VA
CV-66 America- Norfolk VA
CV-67 J. F. Kennedy- Norfolk VA
CV-68 Nimitz- Norfolk VA
CV-69 Eisenhower- Norfolk VA
CV-43 Coral Sea - Norfolk VA
AVT-16 Lexington- Pensacola FL

West Coast

CV-41 Midway- Yokosuka Japan
CV-70 Carl Vincent - Alameda CA
CV-61 Ranger- San Diego CA
CV-64 Constellation- San Diego CA
CV-65 Enterprise- Alemeda CA
CV-63 Kitty Hawk- San Diego CA

INFORMATION SHEET 4.2.11

RADIO-FREQUENCY POWER AMPLIFIERS (CLASS C AMPLIFIERS)

INTRODUCTION

The class C tuned amplifier is biased below the cutoff value of the vacuum tube. With a signal applied under these conditions, the plate current flows in pulses that last for less than an electrical angle of 180°. The class C amplifier is characterized by high plate efficiency and is used to develop radio-frequency power when good fidelity between input and output voltages is not required.

REFERENCES

1. Electronic Circuit Analysis Vol. I and II NAVAIR 00-80-T79.
2. Electronic Circuits, NAVSEA 0967-LP-000-0120.
3. Essentials of Radio Electronics, Slurzburg and Osterheld, McGraw & Hill, Chapter 5, pages 128-161.

INFORMATION

Voltage, Current, and Impedance Relations in Class C Amplifiers

The voltage and current relations of a class C amplifier may best be understood by observing the waveforms in figure 1. The voltage actually applied to the control grid consists of the excitation voltage, e_g, plus the bias voltage, E_{cc}. Normally, at the positive peak of e_g, the grid is driven appreciably positive and draws grid current. The voltage appearing at the plate of the tube consists of the battery voltage, E_{bb}, minus the alternating voltage drop, e_p, across the plate load impedance. The phase relationship is such that the minimum instantaneous plate potential, e_{bmin}, and the maximum grid potential, e_{gmax}, occur simultaneously. The alternating components of the plate and grid voltages are also always sinusoidal, since they are developed across resonant circuits (figure 3).

The plate and grid currents, i_p and i_g, that flow at any instant of time are the result of the combined action of the potentials e_g and e_p at that instant, and so can be determined from these potentials with the aid of a set of characteristic curve of the tube. The plate current is in the form of a pulse flowing for an electrical angle θp less than 180°. The grid current flows only when the grid is positive. The sum ($i_p + i_g$) of instantaneous plate and grid currents represent the total instantaneous space current flowing away from the cathode, and always has a peak value, i_{bmax}, at the instant when the grid and plate potentials are e_{gmax} and e_{bmin}, respectively, as shown in figure 2. The average value of

plate-current pulse over a complete cycle represents the direct current I_b that will be drawn from the source of plate power E_{bb} (figure 1E). The average value of grid-current pulse over a complete cycle is likewise the d-c current I_g, which may be observed by placing a d-c millimeter in the grid current (figure 1F).

The impedance that the load should supply to obtain the proper operation is whatever impedance the tube requires to develop the desired alternating plate voltage when plate-current pulses flow. This impedance can be controlled by varying the coupling of the load to the plate tuned circuit.

Power and Efficiency

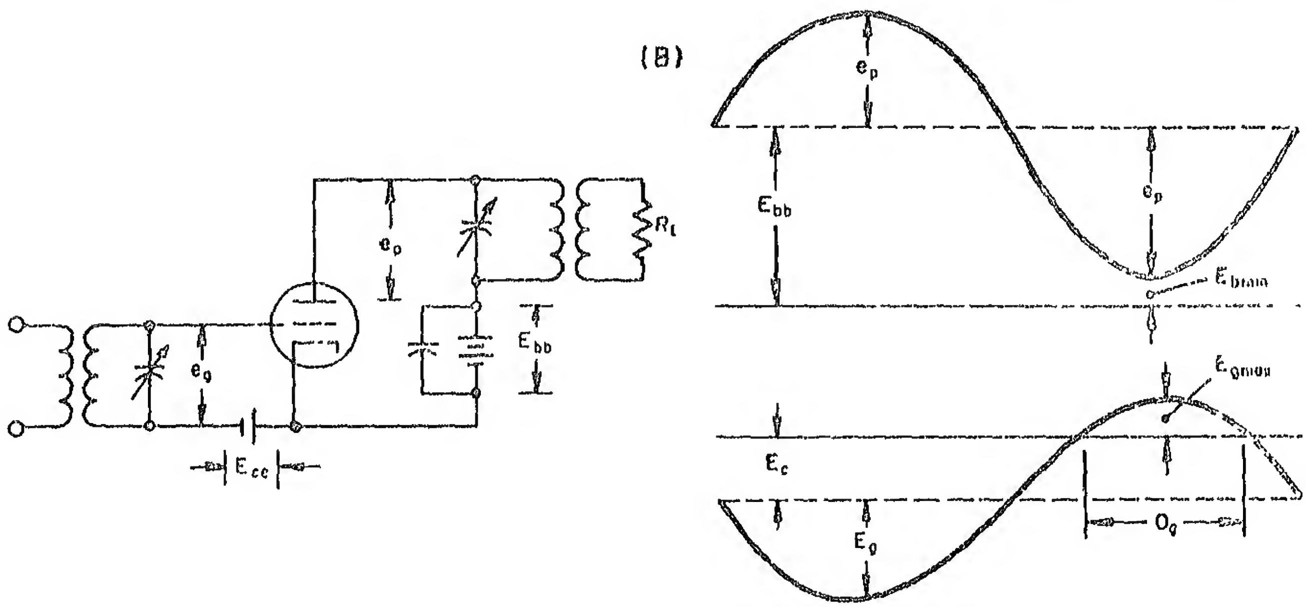
The power delivered to the amplifier by the plate-supply voltage at any instant is the product of instantaneous plate current and the d-c plate-supply voltage E_{bb}, and so varies in the same way as does the instantaneous plate current, as shown in figure 1g. Part of this plate-input power is delivered to the plate tuned circuit and represents useful output, while the remainder is dissipated at the plate of the tube. At any instant, the division of the total power between tuned circuit and tube is in proportion to the voltage drops across these parts of the circuit. Therefore, the plate loss at any instant is equal to the product of the instantaneous plate current and instantaneous plate voltage, and is given by the shaded area of figure 1g. The unshaded area under the total power curve of this same figure represents the energy delivered to the tuned circuit and available for producing useful output. The average input, output, and plate loss are obtained by averaging the instantaneous values of figure 1G over a full cycle.

The high efficiency of the class C amplifier results from plate current flowing only when the instantaneous voltage drop across the tube is low; for example, E_{bb} supplies power to the amplifier only when the largest portion of this power will be absorbed by the tuned circuit. Because of the way in which the instantaneous plate-cathode voltage varies during the cycle (figure 18), the plate efficiency becomes greater as the angle of plate current becomes smaller. If the angle of the plate current flow is very small, plate current will occur only when the plate voltage is at its lowest value, and the efficiency is then high and will approach 100 per cent if e_{bmin} approaches zero. However, making the angle of plate current very small reduces the plate input power and thus the power output, even though the output that is obtained is developed at a high efficiency. In practical work, it is necessary to compromise between high output and high efficiency. Under normal conditions, the balance occurs for angles of plate current between 120° and 150°, corresponding to practical efficiencies of 60 to 80 per cent.

The power required to drive the grid positive comes from the alternating voltage applied to the control grid of the tube. At a given instant, the exciting power is the product of the instantaneous grid current and voltage; therefore, it varies throughout the input cycle. Some of this power is dissipated at the grid in the form of heat, while the remainder is delivered to the bias battery or dissipated in the grid-leak resistor.

Factors Involved in the Operation of Class C Amplifiers

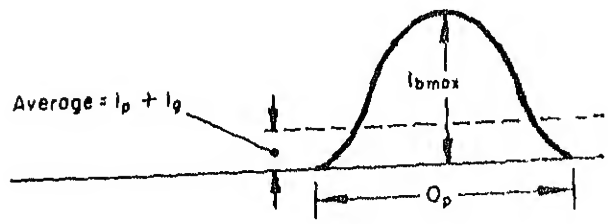
The fundamental factors controlling the operation of a class C amplifier are the maximum space current, i_{bmax} (peak plate current approximately), the number of electrical degrees, θp, plate current flows, the minimum instantaneous plate voltage, e_{bmin}, the maximum instantaneous grid voltage, e_{gmax}, the number of electrical degrees the grid is driven positive θ_g, and the plate supply voltage E_{bb}. The load impedance is not a fundamental factor, since it is dependent upon the above quantities. The efficiency desired, the



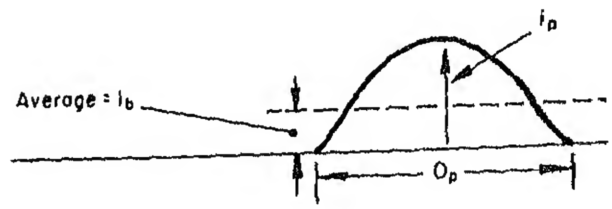
(A) Circuit (C) Grid Voltage

Figure 1

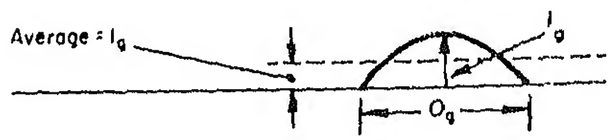
(D) Total Space Current



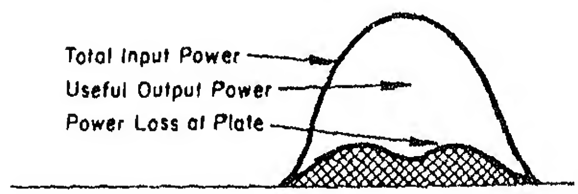
(E) Plate Current



(F) Grid Current

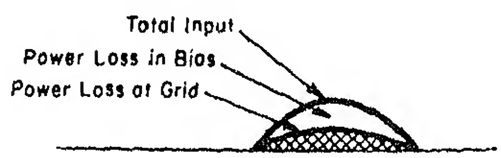


(G) Power Relations in Plate Circuit



(H) Power Relations in Grid Circuit

Figure 1



power output required, and the tube employed, determine the optimum values of the above quantities. The desired of all these quantities is considered to achieve the desired results.

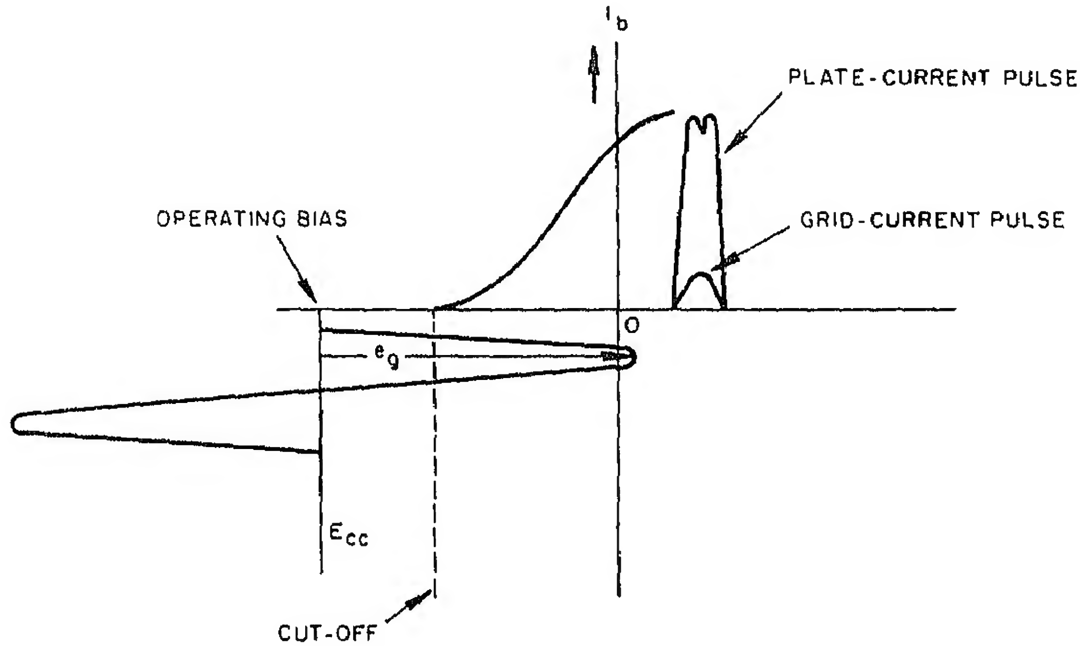


Figure 2

Low gain. Since the class C amplifier responds only to a rather small portion of the input-signal voltage, the voltage gain is small compared with class "A" operation. The power gain (ratio of output power to grid-drive power) is not so high as in class A operation, because the class C tube requires considerable power for operation of its grid circuit. Power is demanded when the grid draws current; this driving power must come from the output of the preceding tube. Hence, class C amplifiers are considerably harder to drive than are class A amplifiers.

Distortion. The class C amplifier produces a current pulse which bears little resemblance to the wave form of the grid signal. The amplifier must be provided with a parallel-resonant tank circuit as a load so as to minimize this distortion. The tank circuit causes back-and-forth motion of electrons which partially compensates for the fact that the tube passes only a part of the positive sinewave of the input. Class C amplifiers are not applicable to audio amplification, but are used only in the radio-frequency section of transmitters, where resonant circuits may be used as load devices.

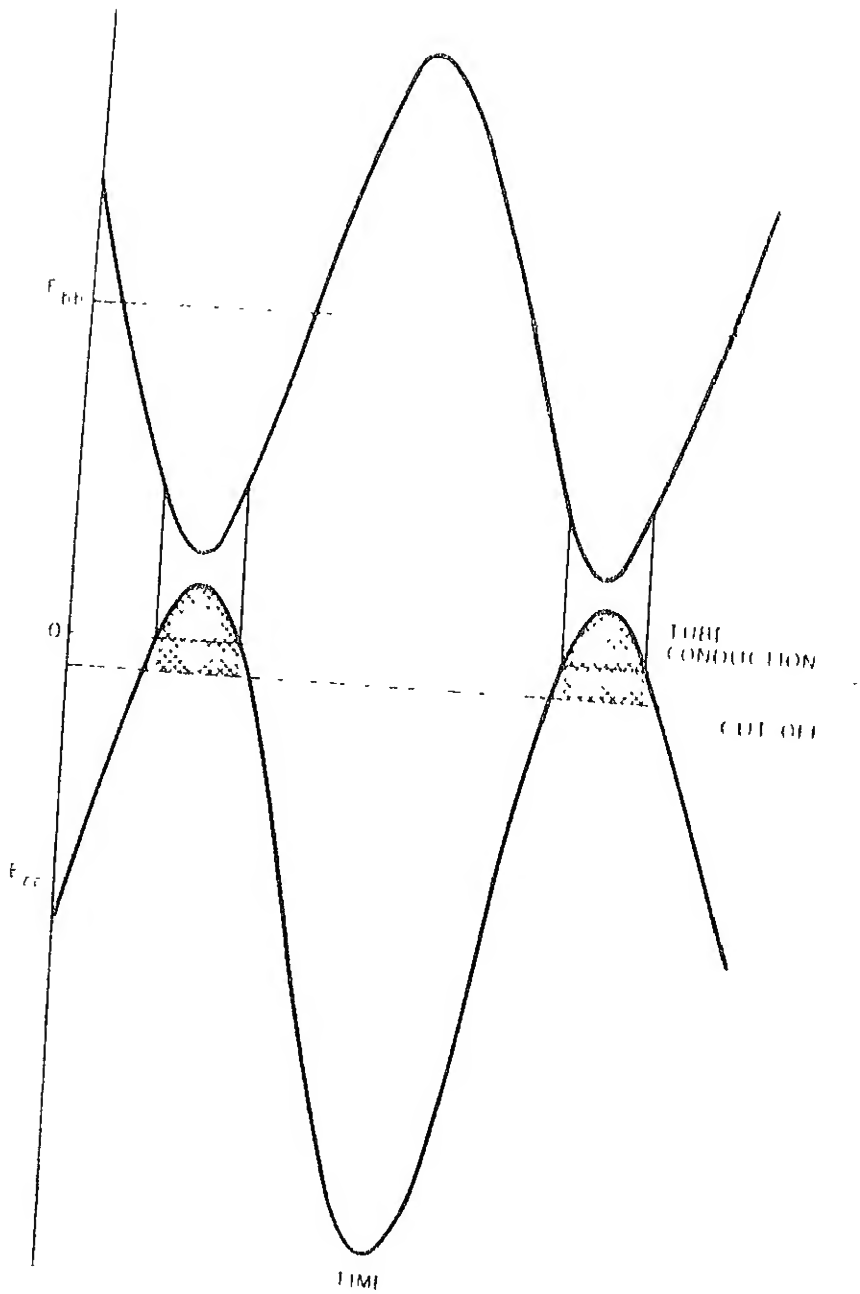


Figure 3

High bias voltage. This amplifier requires a bias voltage which is quite large in comparison to other classes of operation. This is in order to meet the requirements that the current angle be less than 180 degrees. The greater the bias, the smaller will be the angle of plate-current condition, because the grid must overcome the bias voltage in excess of cutoff before the plate begins to conduct. Class C bias is 2 1/2 to 5 times the cutoff value. In larger tubes, this bias is usually supplied by a separate power supply, but it may also be developed by a combination of grid-leak and cathode-bias RC circuits.

Applications of Class C Amplifiers

Power amplifiers for transmitters. The class C amplifier is useful only in radio-frequency amplification where high efficiency is needed. It may be used either as a single-ended amplifier or as a push-pull amplifier to develop large amounts of RF power. Its efficiency is its outstanding characteristic.

Frequency multipliers. The class C amplifier is well adapted for frequency multiplication because of the strong harmonic energy present in the distorted plate-current pulses.

Modulated amplifiers. The modulated amplifier in a modulated transmitter is invariably a class C operated tube. Class C amplifiers will modulate satisfactorily, without distortion of the audio component regardless of the type of modulation. The amplifier cannot be made to amplify a modulated signal once it is produced, without causing distortion, but it will allow audio signals to be modulated into the carrier wave in it without loss of the audio waveform. (For a full explanation of this, see the discussion of amplitude modulation.)

NOTETAKING SHEET 4.2.1N

RADIOFREQUENCY POWER AMPLIFIERS

REFERENCES:

1. Electronic Circuit Analysis, Vol. I & II NAVAIR 00-80-T-79.

2. Electronic Circuits, NAVSEA 0967-LP-000-0120.

3. Essentials of Radio Electronics, Slurberg, Morris, Osterheld, McGraw & Hill, Chapter 5, pages 128-161.

NOTETAKING OUTLINE:

A. Triode Vacuum Tube Amplifiers

   1. General Information

   2. RC Coupling

   3. Vacuum Tube Characteristics

B. Class C Amplifiers

1. General Information

2. Operating characteristics

a. Characteristic curve

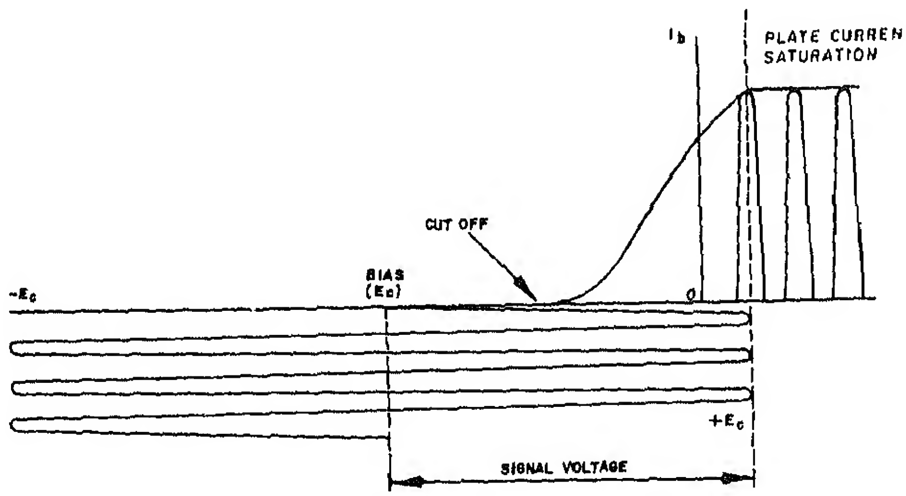


Figure 1 Ec Ib Curve

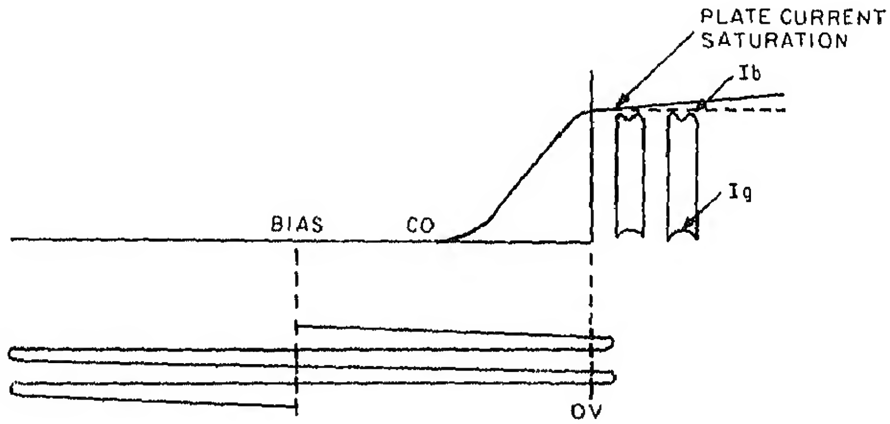


Figure 2. EcIb Curve with Ib & Ig.

b. Basic circuit

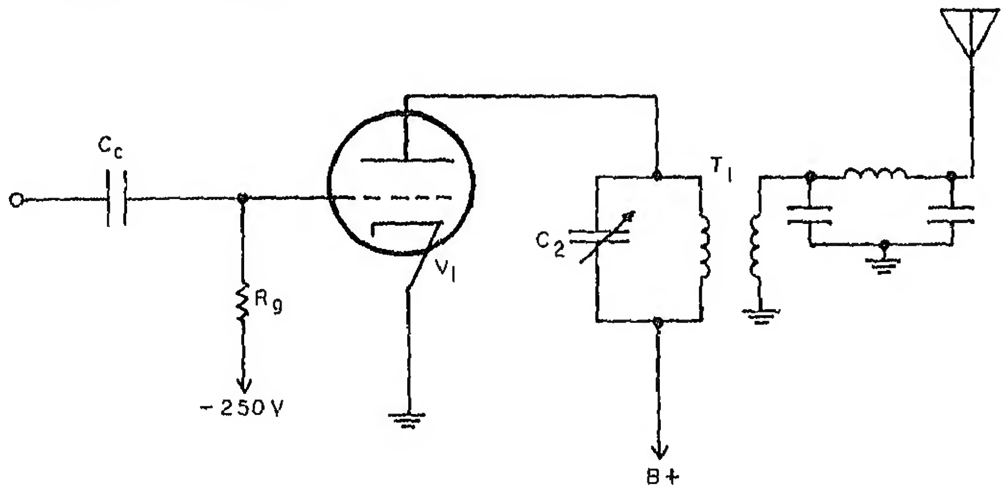


Figure 3. Basic Circuit

C. Theory of Operation

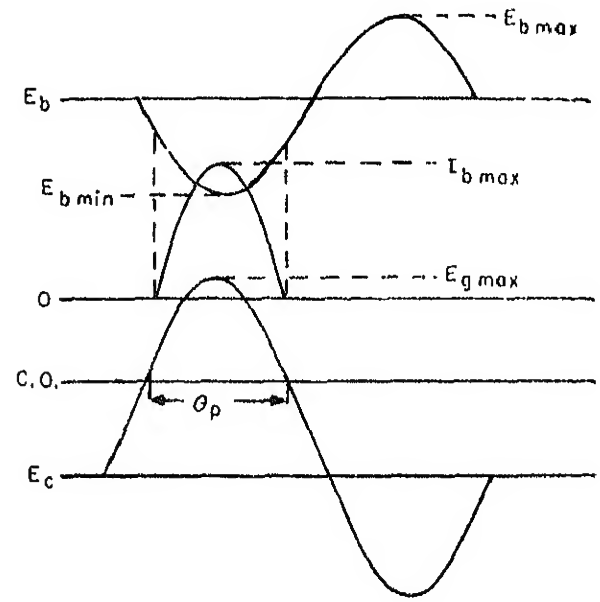


Figure 4 Grid-Plate Signal

3. Bias Methods verses Angle of Plate Current, θp

a. Fixed Bias

b. Grid-Leak Bias

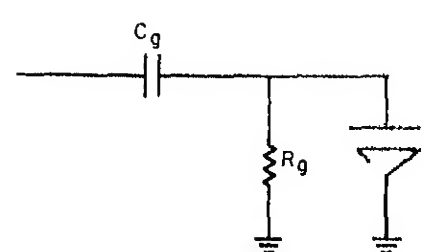


Figure 5 Negative Clamper

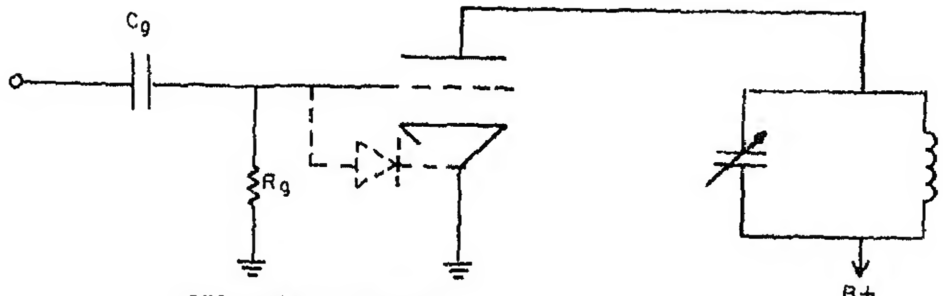


Figure 6 Grid-Leak Bias

c. Angle of Plate Current, θ_p

(1)

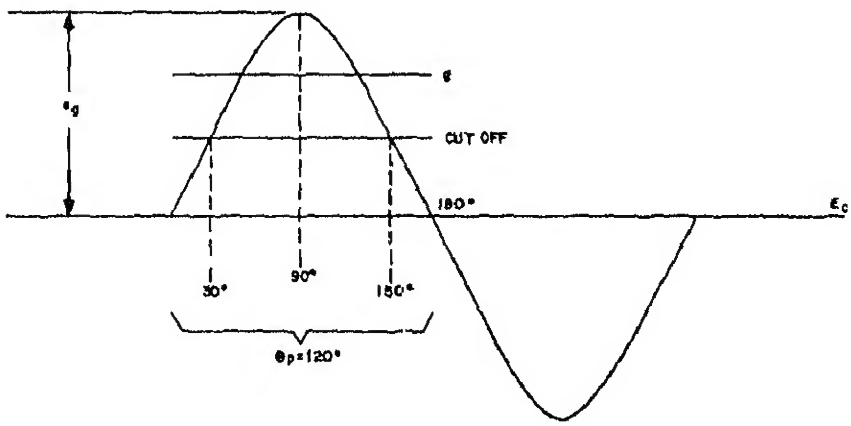


Figure 7 Grid Drive Signal

(2)

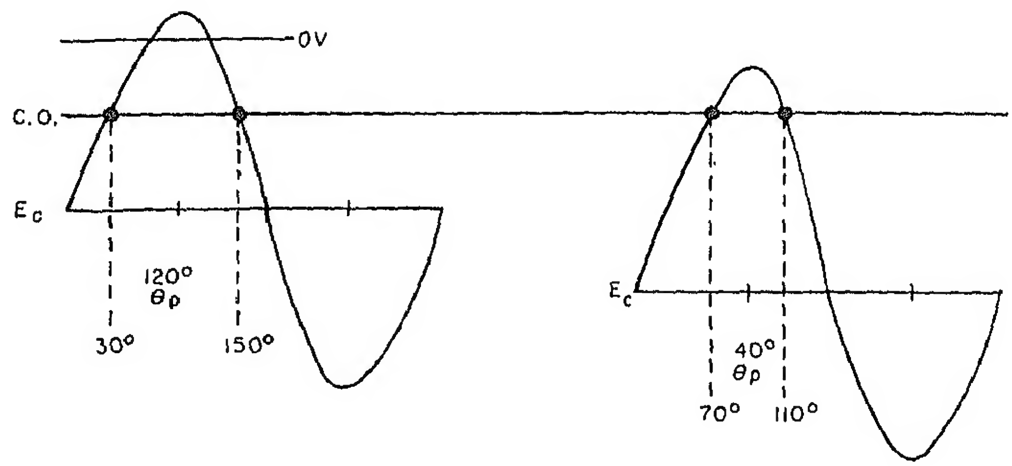


Figure 8 Increasing Bias

(3)

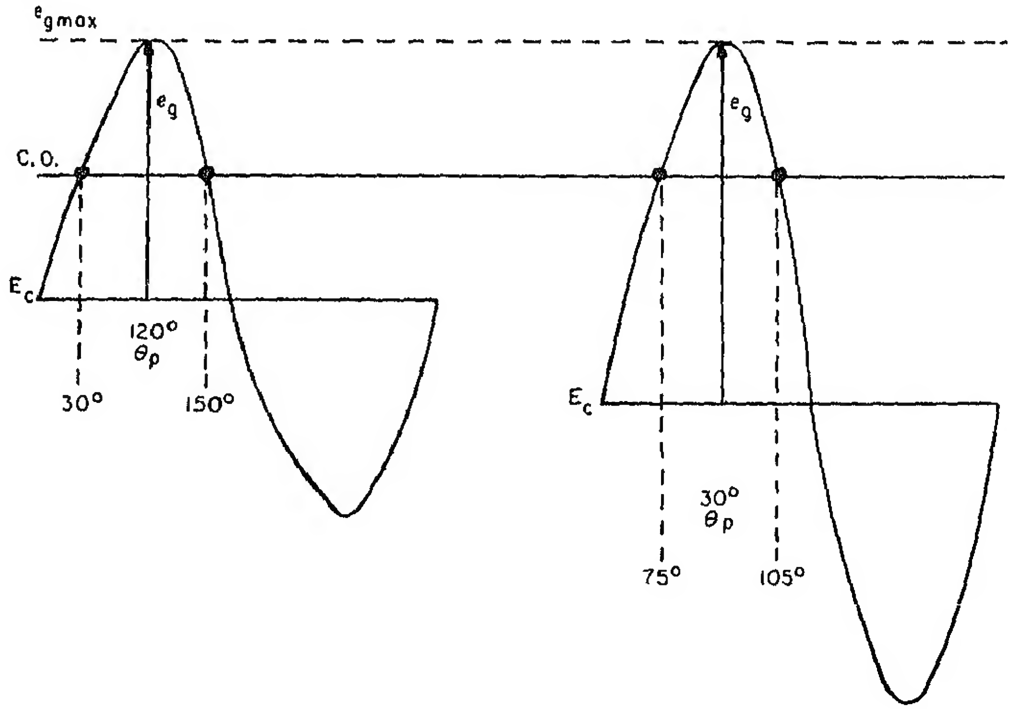


Figure 9 Increasing Drive Signal Grid-Leak Bias

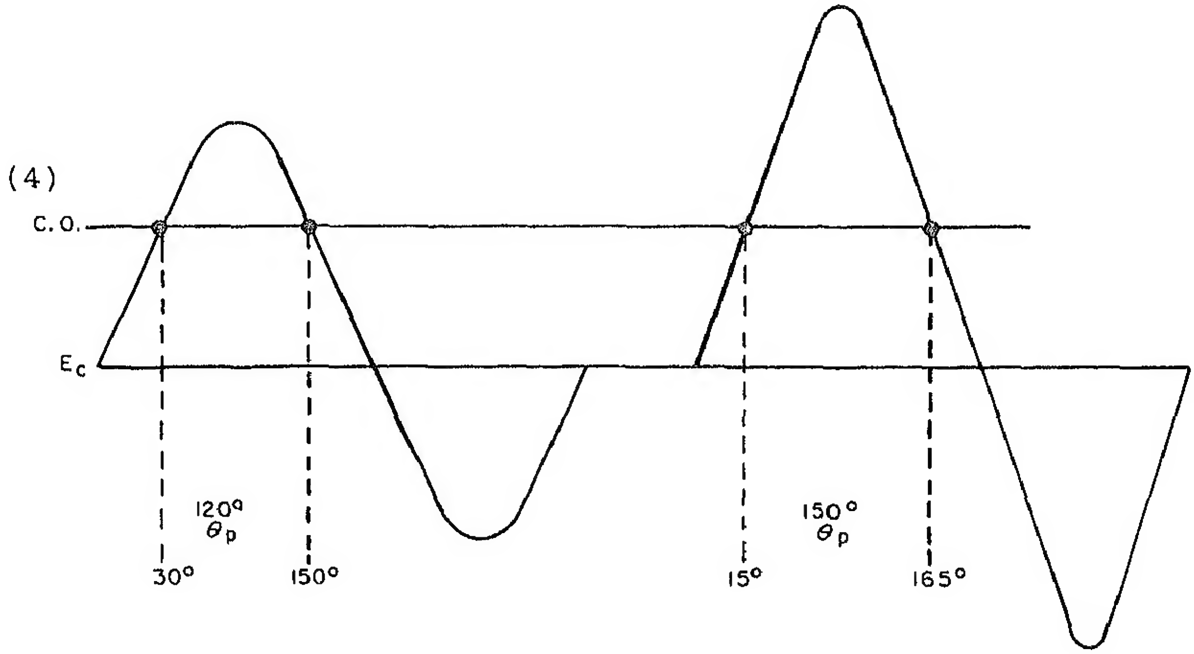


Figure 10 Increasing Drive Signal Fixed Bias

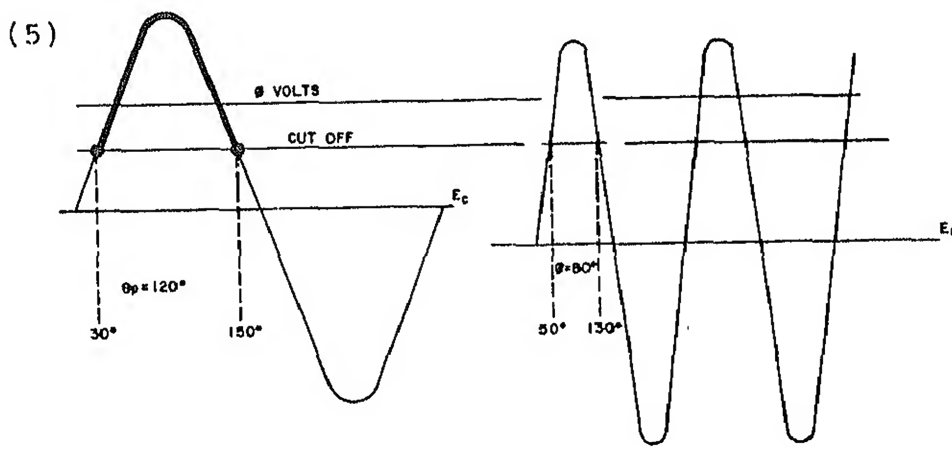


Figure 11 Increasing Frequency (Grid-Leak Bias)

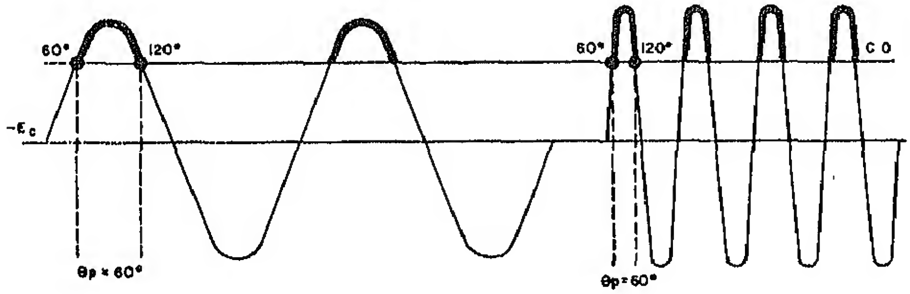


Figure 12 Increasing Frequency (Fixed Bias)

(7)

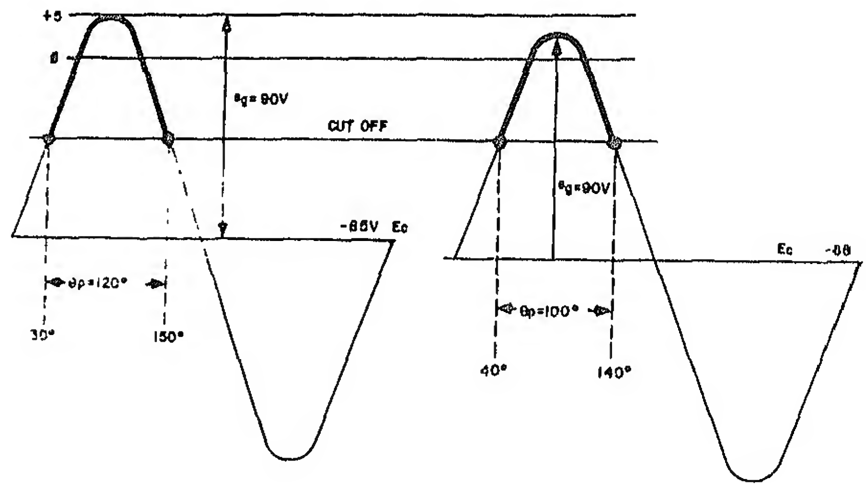


Figure 13 Increasing RC Time Grid-Leak Bias

(8)

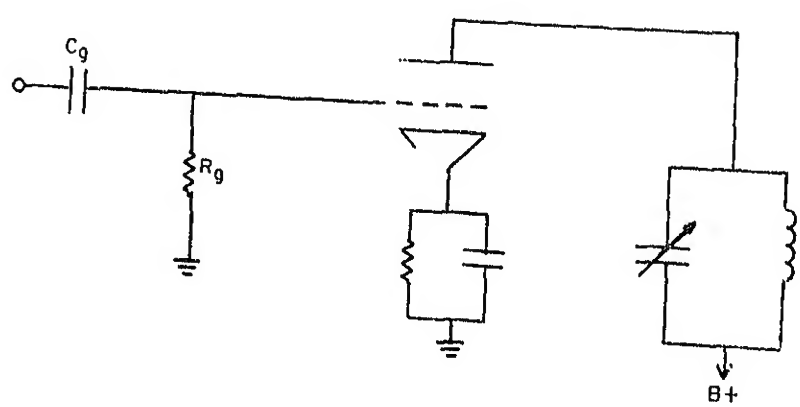


Figure 14 Combination Bias

C. Buffer Amplifiers and Harmonic Generators

1. Buffer Amplifiers

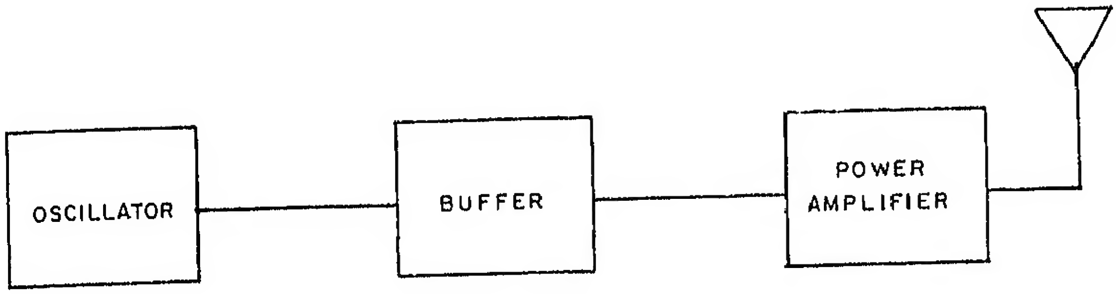


Figure 15 Buffer Amplifier

2. Harmonic Generators

   a. Need for

   b. Harmonic generation

   c. Operation

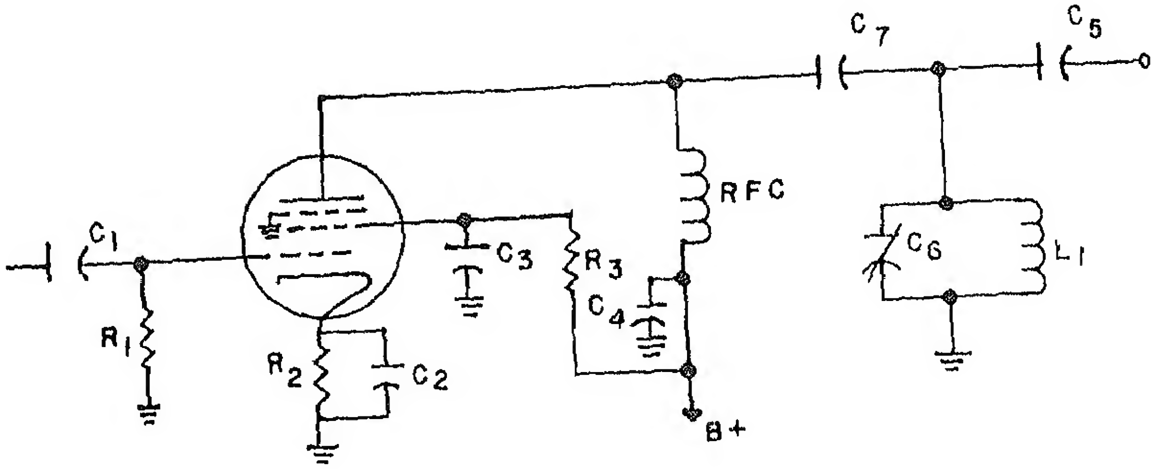


Figure 16 Vacuum Tube Multiplier

(1) Circuit analysis

(2) Principles of operation

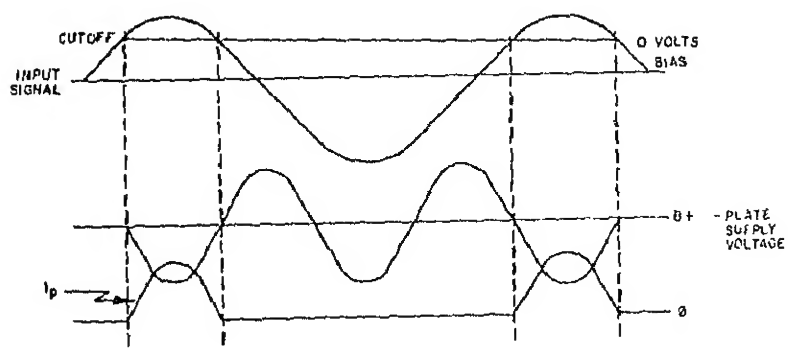


Figure 17 Input/Output Waveform Synchrogram

d. Application

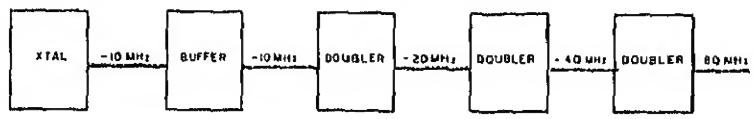


Figure 18 Master Oscillator

D. Radio frequency Power Amplifiers

1. Characteristics of RF power amplifiers

2. Single-ended class C amplifiers

a. General considerations

b. Specific considerations

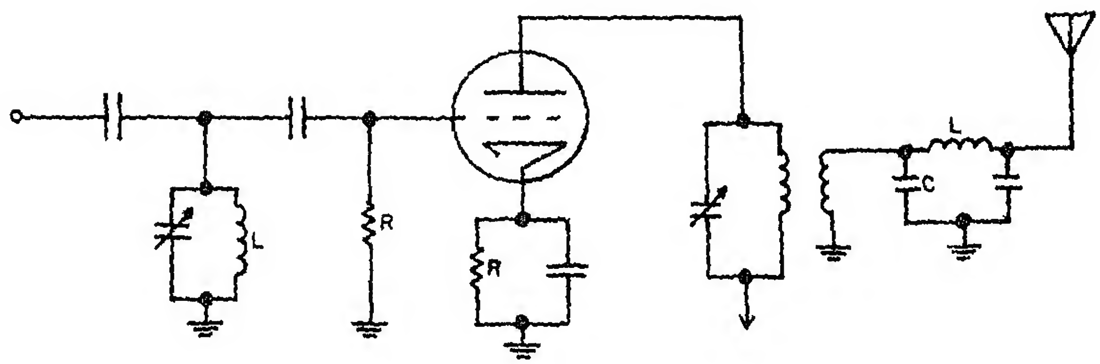


Figure 3a. Basic Circuit

3. Linear RF amplifiers

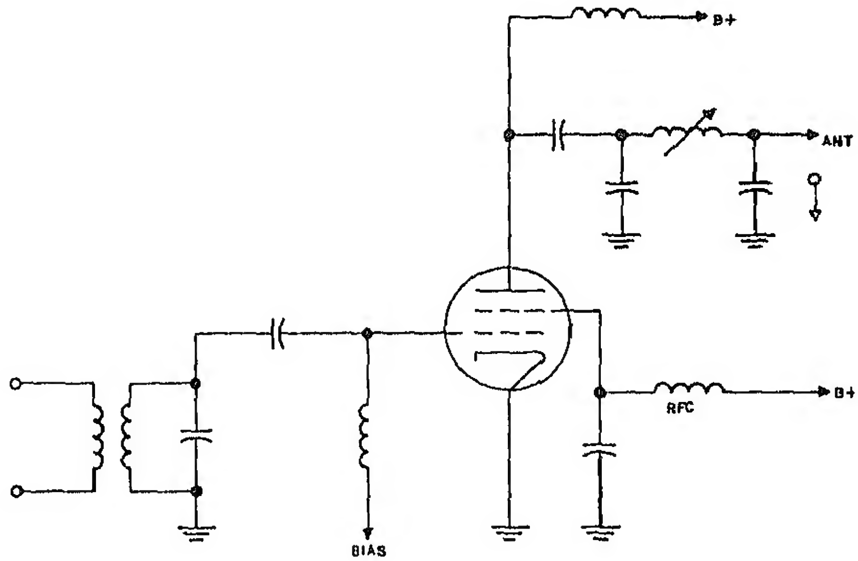


Figure 19 Tetrode Linear Power Amplifier

4. Adjustment procedures

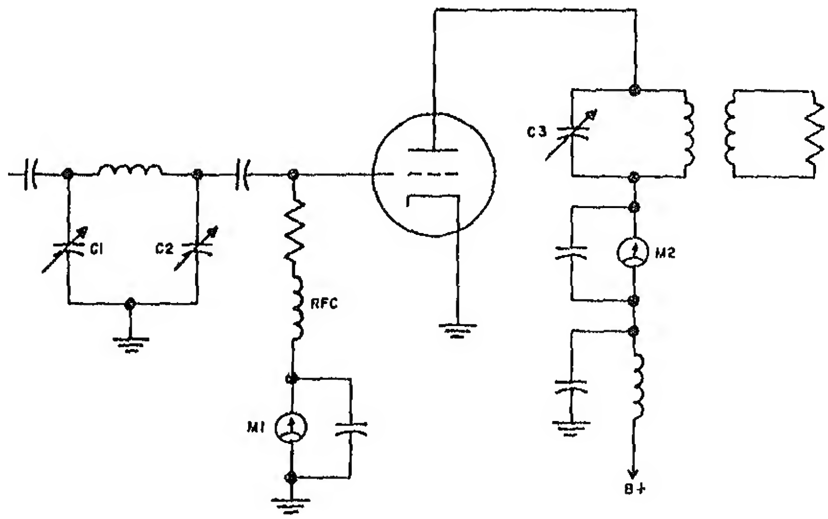


Figure 20 Typical RF Meter Placement

5. Neutralization

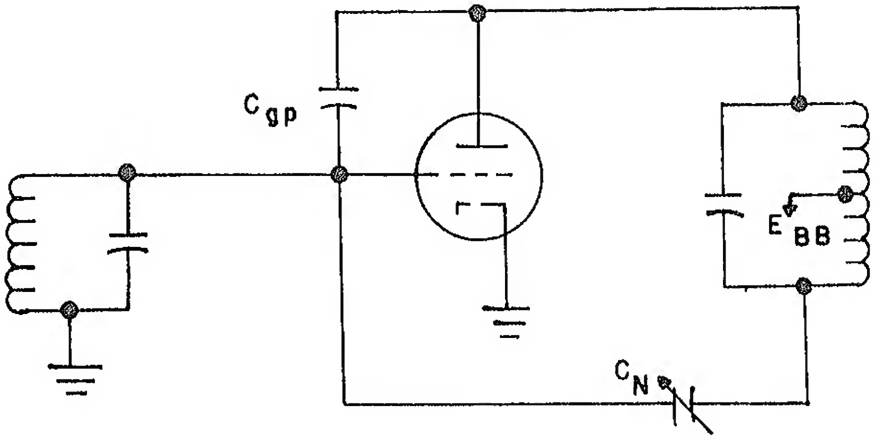


Figure 21. Plate Neutralization

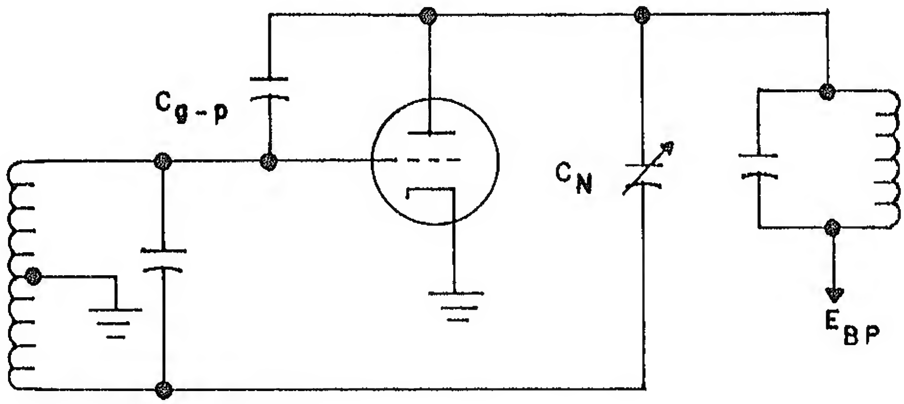


Figure 22. Grid Neutralization

6. Parasitic Oscillations

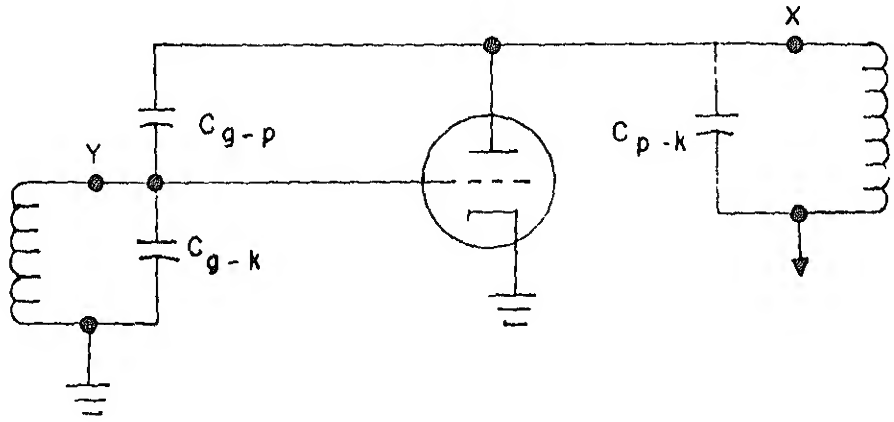


Figure 23. Remedies for Parasitic Oscillations

INFORMATION SHEET 4.3.1I

AMPLITUDE-MODULATED TRANSMITTERS

INTRODUCTION

The ideas contained in this information sheet are not peculiar to the laboratory transmitter alone, but are suitable for application to any amplitude-modulated or CW transmitter. The types of stages and their purposes will not vary from transmitter to transmitter. Minor changes may be made for frequency stability or changing frequency range of a transmitter, but the methods of troubleshooting are essentially the same for all transmitters.

REFERENCES

1. Electronic Circuit Analysis, Vol. II, NAVAIR 00-80-T-79, pp 9-1 to 9-3.

2. Communications, NAVSEA 0967-LP-000-0010, pp 1-1 to 1-6.

3. Essentials of Radio Electronics, Slurzberg and Osterheld, McGraw-Hill, Second Edition, Chap 1, pp 7-12.

INFORMATION

Carrier generation, theory of operation

The first point of interest will be the discussion of how the RF carrier is generated. This is essentially the same for either an amplitude-modulated transmitter or a CW transmitter. The signal must first be generated, raised to the desired amplitude and frequency, and then fed to the antenna.

The signal is generated in the oscillator. The output of the oscillator is maintained at some desired frequency and is unvarying in amplitude. All oscillators take some of the amplified signal and feed it back to the grid in such a way that the tube is alternately driven to saturation and then to cutoff. The signal fed back to the grid will draw grid current on positive excursions, creating an excess of electrons in the grid circuit. When checked with a high-impedance voltmeter, there will always be a negative voltage present on the control grid of an oscillator. Operation may be quickly checked by testing for the negative voltage. Bear in mind that this is only a check for operation and does not establish that the oscillator is developing the correct frequency. If the negative voltage is not present, conventional methods of troubleshooting may follow, such as checking the tube, making voltage and resistance checks, as well as visual inspection of the stage.

negative voltage on the control grid. If there is no distinct dip in plate current when tuning the plate tank, it is advisable to check the source of the signal, the oscillator. Use the above mentioned test for the oscillator. If the oscillator is functioning properly, then it is apparent that there is trouble in the buffer stage or the circuit coupling the energy to the buffer. In either event, the device used to track down the faulty component will be the VTVM.

In the final amplifier, in most transmitters, a panel meter will be applied to both the grid and plate circuits to monitor the current. Presence of drive is readily apparent, because on positive excursions, the grid is positive with respect to its cathode and the resulting current drawn in the diode circuit is indicated directly on the grid-current meter.

It can be seen, then, that the RF generating portion of a transmitter may be readily checked, stage by stage, merely by checking for a negative voltage on the control grid. This negative voltage is present on the control grid of all the conventional oscillators and is a valid test. The amplitude of the voltage present depends on the amplitude of signal developed, which is dependent in turn on the amount of loading and the capabilities of this stage as an amplifier. Any stage operated as a doubler or multiplier must be driven hard enough to draw grid current. The final power amplifier is operated class C and usually some form of grid-leak bias is used, since it is self-adjusting.

The modulator section of a transmitter also lends itself to troubleshooting with the VTVM. The scope is useful largely in determining the percentage of modulation present in the output waveform, and since all stages are handling audio frequencies, it can be used to the same advantage as the voltmeter. When it is determined that there is no modulation present, a modulator section may be checked for presence of an audio signal. This is done by starting at the source, such as the tone oscillator or audio signal generator, measuring the amplitude of signal at the grid of the first audio stage and checking for its presence at the grid of the subsequent stages. The scope employed in this capacity will reveal not only the presence of the signal, but also if there has been any distortion impressed on the signal.

Additional aids for monitoring modulations are provided in Navy transmitters by use of sidetones. Some modulator stages have a separate winding on the modulation transformer making it possible to monitor the operation of the modulator stage only. Others, like the AN/ARC-27, have a much better feature, where sidetone monitoring is accomplished by a detector stage at the RF output of the entire transmitter. In this way, the side tone not only monitors the modulation, but reveals that the RF section of the transmitter is working.

NOTETAKING SHEET 4.3.1N

AM TRANSMITTERS

REFERENCES:

1. Electronic Circuit Analysis, Vol. I & II, NAVAIR 00-80-T-79 pages 7-4 to 7-10, 9-1 to 9-4.

2. Communications, NAVSEA 0967-LP-000-0010 pages 1-1 to 1-6.

3. Essentails of Radio Electronics, Slurzburg & Osterheld, McGraw-Hill, Second Edition Chapter 1, pages 7-12.

NOTETAKING OUTLINE:

A. General Information

    1. Reasons for carrier modulation

    2. Modulation

    3. Basic requirements of a transmitter

4. Classes of transmission

a. Classified by type modulation

b. Classified by frequencies

B. Radio Frequency Generation

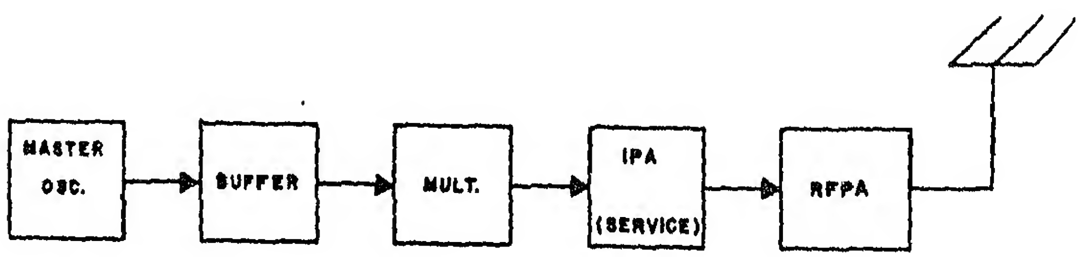


Figure 1 RF Frequency Generator

C. Audio Frequency Generation

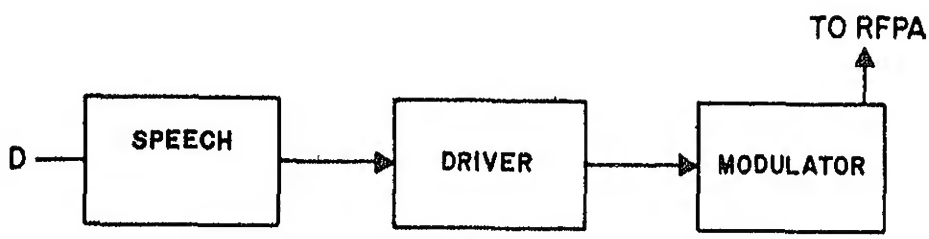


Figure 2 Audio Frequency Generator

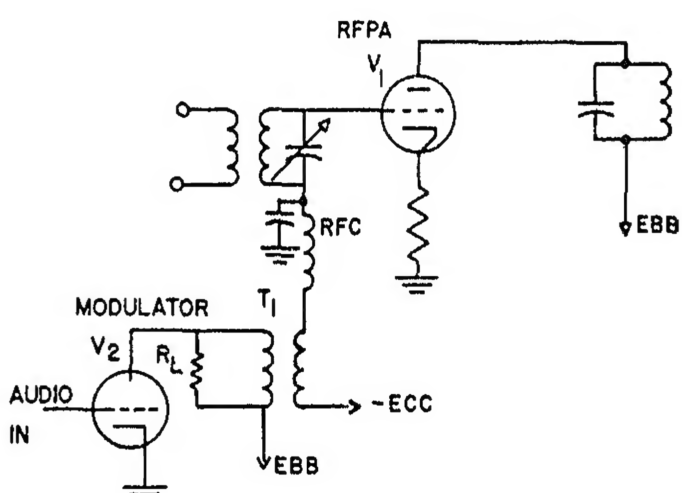


Figure 3 Grid Modulation

D. Amplitude Modulation

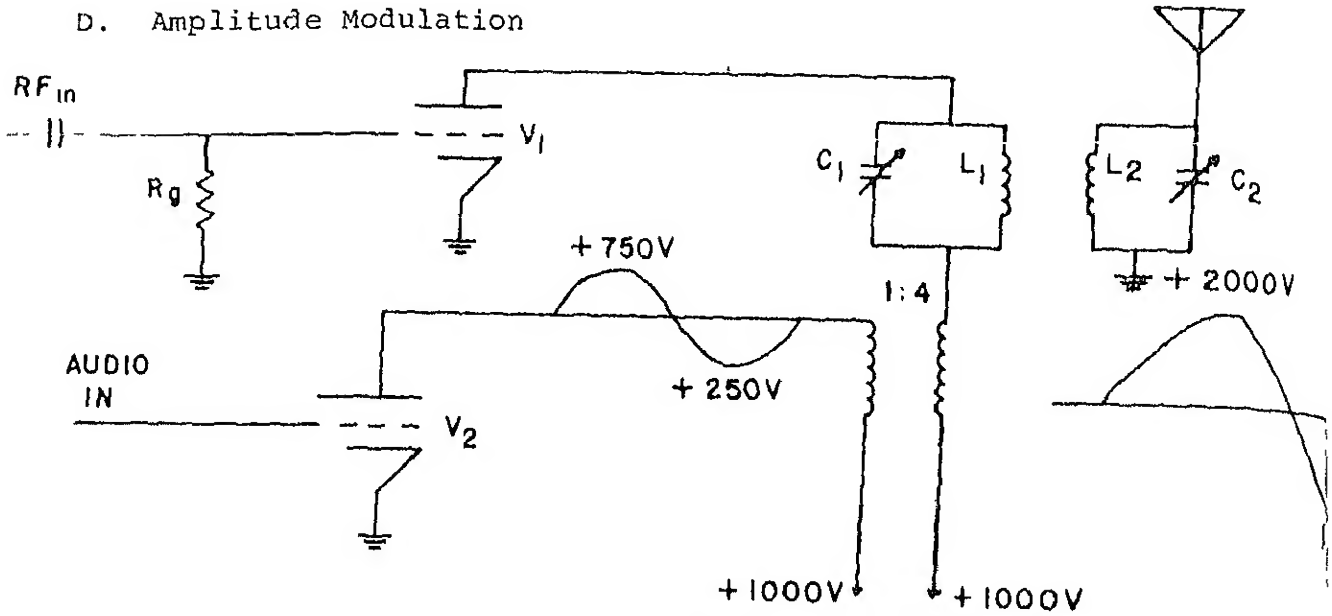


Figure 4 Plate Modulation

1. Amplitude-modulated waveform

2. Typical operation

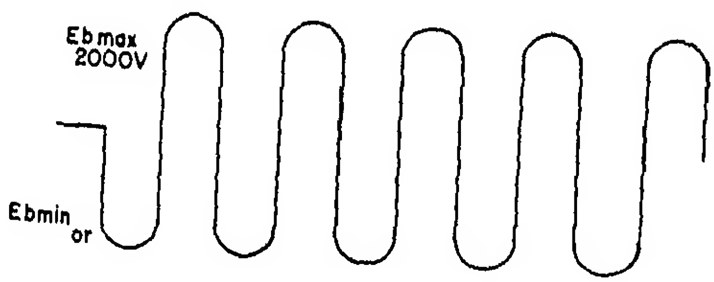


Figure 5 Plate Voltage

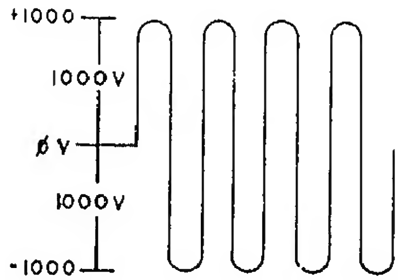


Figure 6. Voltage Swing

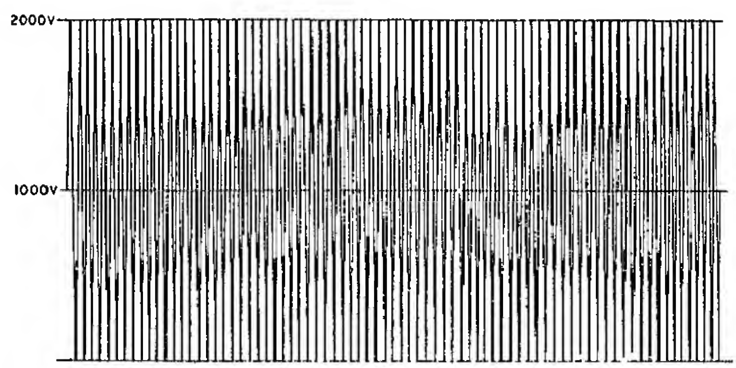


Figure 7. Unmodulated RF

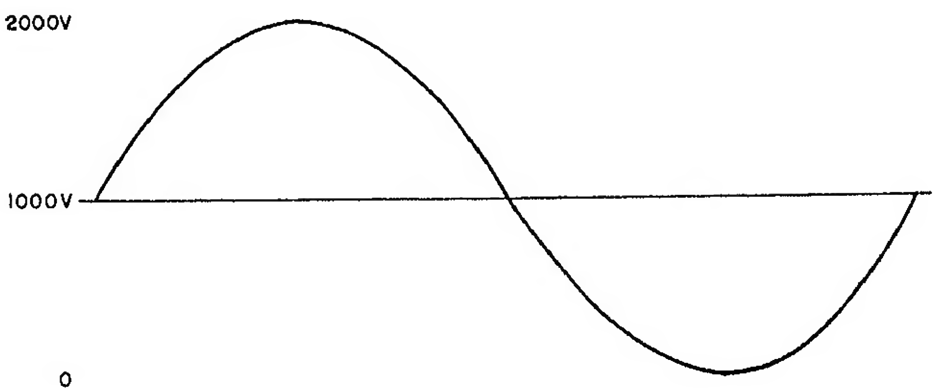


Figure 8. Audio Signal

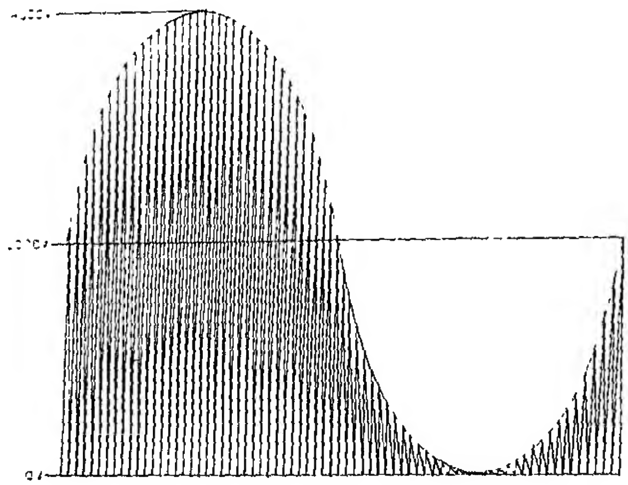


Figure 9 PA Output

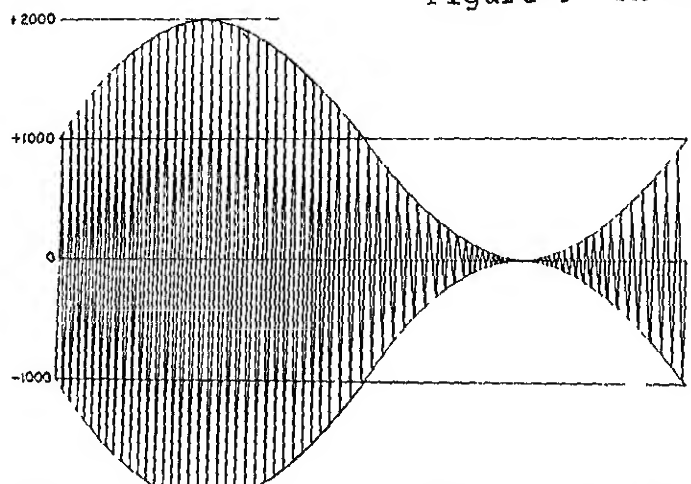


Figure 10 Antenna Tank

Percentage of Modulation

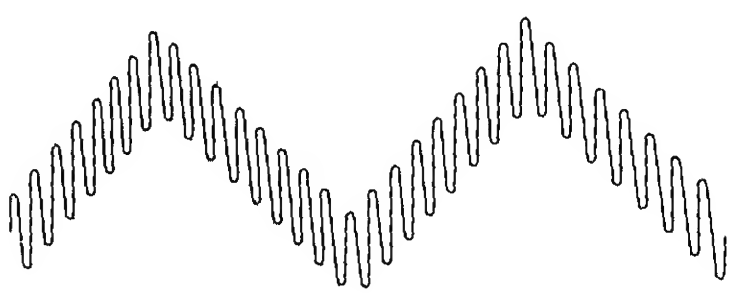


Figure 11 RF Varying at an Audio Rate

E. Transmitted Signal

1. Frequency Analogy

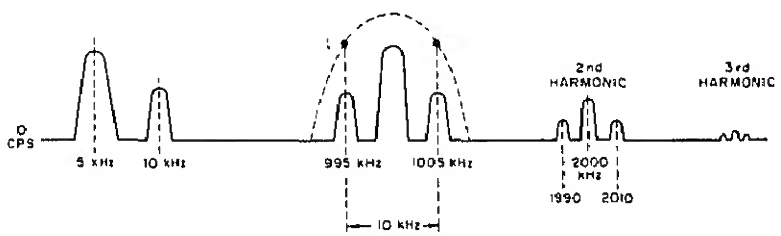


Figure 12 Frequency Spectrum

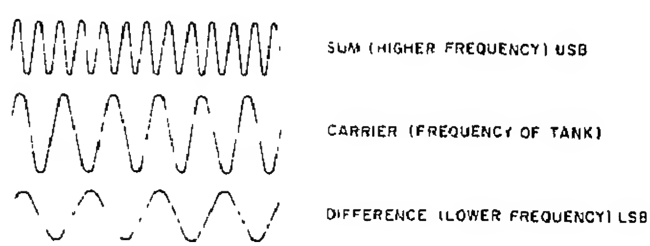


Figure 13 Carrier and Sidebands

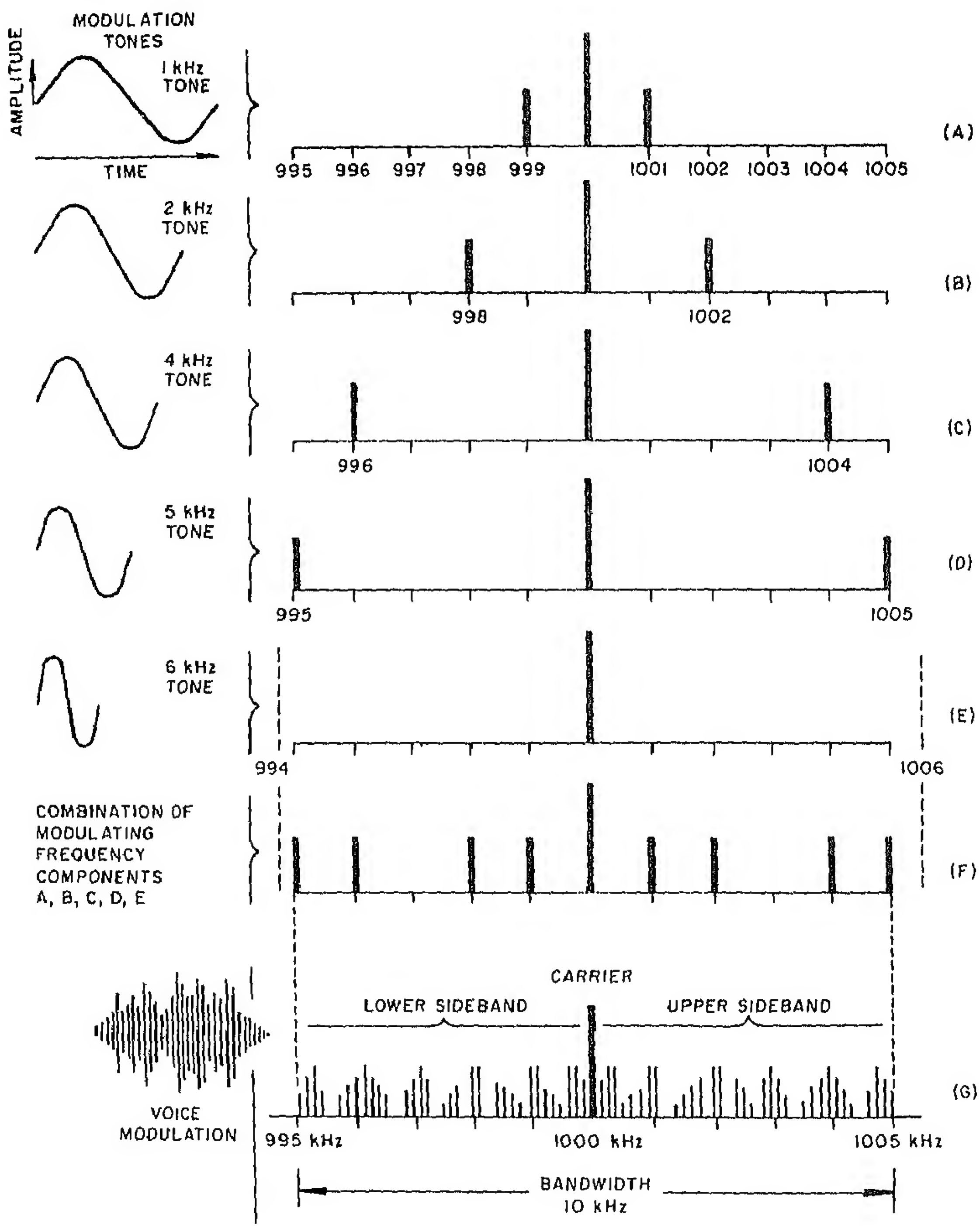


Figure 14 Bandwidth Variation

2. Power Relationships in AM Waveforms

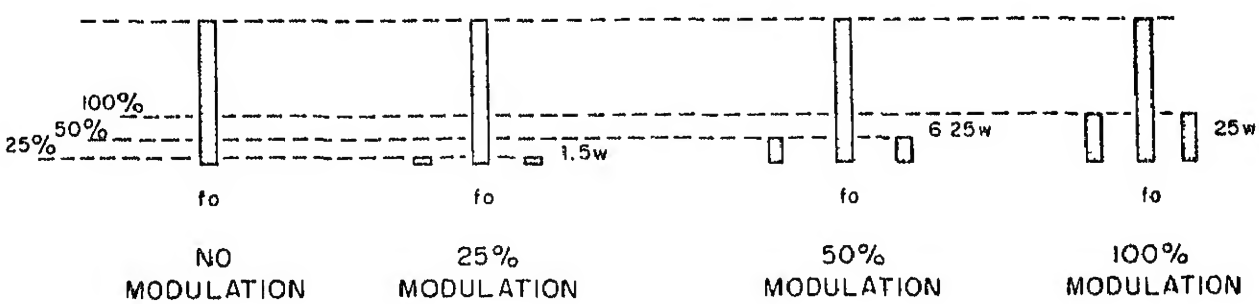


Figure 15 Power Relationship in Sideband

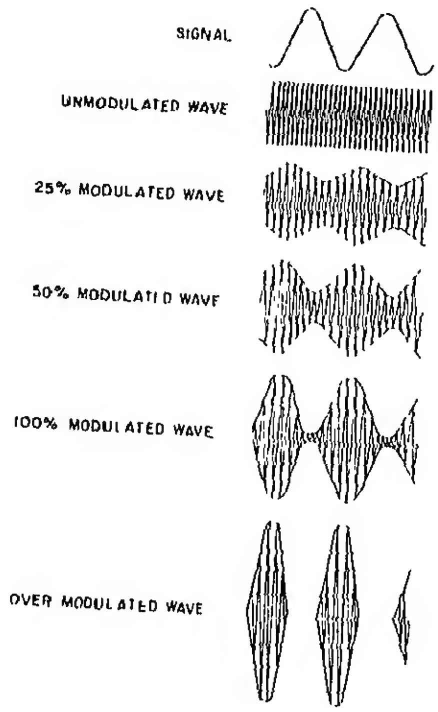


FIGURE 16 Amplitude Modulation

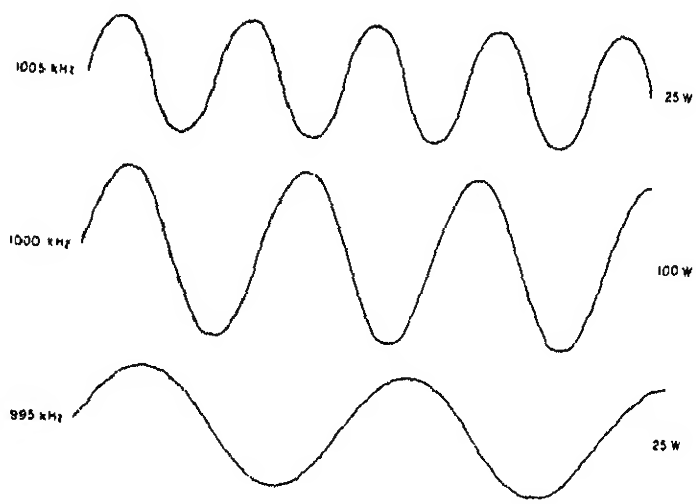


Figure 17 Relative Power

3. Systems of amplitude modulation

INFORMATION SHEET 4.4.1I

AMPLITUDE-MODULATED RECEIVERS

INTRODUCTION

The essentials of an AM receiver include both the basic requirements and the characteristics. This information is provided to address both of these areas for the student.

REFERENCES

1. Communications. NAVSEA 0967-LP-000-0010, pages 1-1 to 1-5, 1-46.

2. Electronic Circuit Analysis, Vol. II. NAVAIR 00-80-T-79, pages 9-1 to 9-3.

3. Slurzberg, Morris, and William Osterheld. Essentials of Radio Electronics. Second Edition. N.Y.: McGraw-Hill Book Company, Inc. Chapter 11, pages 435-466; Chapter 5, pages 593-626.

INFORMATION

Essentials of AM Receivers

1. Basic requirements:

    a. Collection: An antenna is necessary to pick up RF energy emanating from a transmitter.

    b. Selection: Some means of tuning must be provided so that only the desired signal will be selected.

    c. Detection: The detector provides a means of recovering the intelligence on the RF signal by a process called demodulation.

    d. Reproduction: The signal is reproduced by a headset, a speaker, or any other device that converts electrical energy into audio energy sufficiently large enough to be heard by the human ear.

2. Essential characteristics of AM receivers:

    a. Sensitivity

(1) A measure of a receiver's ability to reproduce weak signals.

(2) The minimum signal voltage required to be applied to the receiver's antenna to produce a standard audio output power with a specified minimum signal-to-noise ratio.

(3) Usually expressed in microvolts, or decibels, or decibels below 1 volt. This information will be found in the MIM for that particular receiver.

b. Selectivity

(1) The measure of a receiver's ability to differentiate between the desired signal and the undesired signals.

(2) Determined by the bandpass and the number of tuned circuits preceding the second detector.

c. Signal-to-noise ratio

(1) Ratio of output signal power to output noise power at a specified value of modulated carrier input.

(2) The noise in this ratio is the noise generated within the receiver.

(3) "Noise" is defined as <u>the random motion of electrons or changes having no particular phase or frequency</u>.

(4) Noise varies directly with the following:

(a) Temperature.

(b) Bandwidth (if circuit is selective).

d. Fidelity

(1) Fidelity is the ability of a receiver's output to faithfully reproduce the essentials of the input.

(2) Reproduction of the lower modulating frequencies is primarily determined by the RC coupling in the audio stages.

(3) Reproduction of the higher modulating frequencies is primarily determined by the amount of sideband cutting in the tuned circuits preceding the second detector.

e. Stability

(1) Stability is the degree of receiver output variation, over a period of time, with a constant input signal.

(2) Stability is affected by the following:

(a) Power supply variations.

(b) Temperature variations.

(c) Mechanical construction.

(d) Unwanted (parasitic) oscillations.

NOTETAKING SHEET 4.4.1N

AMPLITUDE-MODULATED RECEIVERS

REFERENCES:

1. Communications. NAVSEA 0967-LP-000-0010, pages 1-1 to 1-5, 1-46.

2. Electronic Circuit Analysis, Vol. II. NAVAIR 00-80-T-79, pages 9-1 to 9-3, 9-8 to 9-17.

3. Slurzberg, Morris, Osterheld, Essentials of Radio Electronics, 2nd edition. McGraw-Hill Book Co., Chapter 11, pages 435-466; Chapter 5, pages 593-626.

NOTETAKING OUTLINE:

A. Essentials of AM Receivers

    1. Basic requirements

    2. Essential characteristics of AM receivers

        a. Sensitivity

        2. Selectivity

c. Signal-to-noise ratio

d. Fidelity

e. Stability

3. Classification of receivers

a. Frequency

b. Modulation types

c. Transceivers

B. Simple receiver: Crystal Receiver

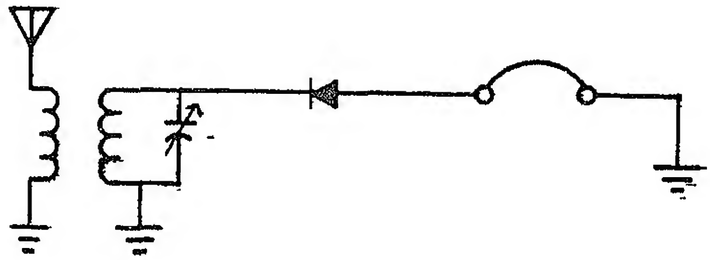


Figure 1 Crystal Receiver

C. Complex Receivers

1. Tuned radio-frequency receiver (TRF)

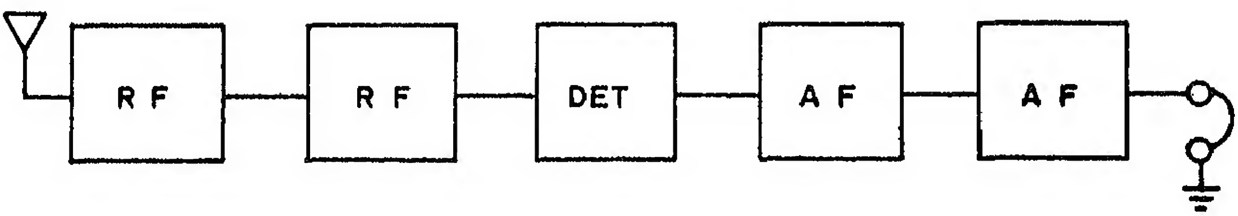
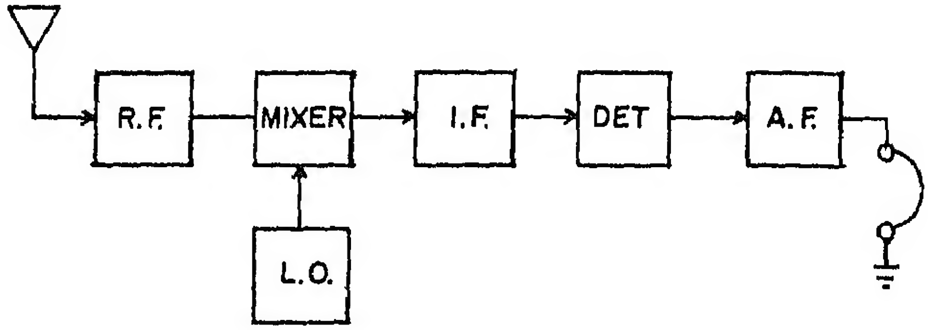


Figure 2 TRF Receiver

2. Superheterodyne receiver



NOTE: RF stage not necessary for basic superheterodyne.

Figure 3 Basic Superheterodyne Receiver

a. Principles of operation

b. Stages and their functions

(1) RF amplifier or preselector

(2) Local oscillator

(3) First detector

(4) IF amplifier

(5) Audio detector

(6) AF amplifier

(7) Comparison of superheterodyne & TRF

(a) Advantages

(b) Disadvantages

D. Major Differences Between Vacuum Tube and Transistor Rece

E. Essentials of Single-Sideband (SSB) Receivers

(Use this page for additional notes)

INFORMATION SHEET 4.5.1I

INTRODUCTION TO UHF

INTRODUCTION

The study of UHF requires that you possess certain background information. This information sheet is provided to you so that you can learn this general information.

REFERENCES

1. Electronic Circuit Analysis, Vol. II, NAVAIR 00-80-T-79, pages 12-1 to 12-6.

2. Basic Electronics, Vol. 2, NAVPERS 10087-2, pages 88-97.

3. HSI, NAVAIR 16-30ARC51-2, pages 4-164-4.

INFORMATION

A. Radio frequency

   1. Definition - Any frequency whose electromagnetic field can be radiated over great distances.

   2. Useful RF spectrum is from approximately 10 kHz to 300,000 MHz.

   3. UHF spectrum

      a. 300 MHz to 3000 MHz.

      b. UHF characteristics begin at 100 MHz.

      c. The band of frequencies from 100 MHz to 300 MHz is a transitional band.

      d. Military UHF transceivers generally operate from 225.00 MHz 399.95 MHz.

B. Advantages of UHF

   1. More frequencies available.

      a. Primary advantage.

      b. Range of 225.00MHz-399.95MHz gives 3500 channels spaced .05 MHz apart.

2. UHF spectrum has less static.

    a. Atmospheric noise decreases as frequency increases.

    b. Communications are more reliable and intelligible.

3. Smaller components

    a. Less weight.

    b. Smaller equipment (less space).

4. Smaller antenna

    a. Important in aviation.

    b. Streamlining is critical in newer jet aircraft.

C. <u>Disadvantages of UHF</u>

1. Line-of-sight transmission limitations

    a. Height of antenna.

    b. Curvature of the earth.

    c. Obstacles (mountains, etc.)

2. Various phenomena

    a. Natural - sun spots, etc.

    b. Critical length of leads.

        (1) Stray capacity.

        (2) Lead inductance.

3. Small parts

    a. Delicate.

    b. Hard to work on.

NOTETAKING SHEET 4.5.1N

INTRODUCTION TO UHF

REFERENCES:

1. Electronic Circuit Analysis, Vol. II, NAVAIR 00-80-T-79, pages 12-1 to 12-6.

2. Basic Electronics, Vol. 2, NAVPERS 10087-2, pages 88-97.

3. HSI, NAVAIR 16-30ARC-51, pages 4-1 to 4-4.

NOTETAKING OUTLINE:

A. General Information

   1. Radio frequency

   2. Advantages of UHF

   3. Disadvantages of UHF

B. Power Generation Considerations

1. Interelectrode capacitance

2. Transit time

3. Lead inductance

4. Skin effect

C. Special Circuits

1. Hubbard tanks

2. Grounded-grid amplifiers

3. Lighthouse tubes

4. Current tuned tanks

Reasons for Multiple Conversion Transceivers

1. Transmitter section

2. Receiver section

E. Antenna

NOTETAKING SHEET 4.6.1N

UHF TRANSCEIVER BLOCK DIAGRAM

REFERENCES:

1. Basic Electronics, Vol. 2, NAVPERS 10087-C, pages 88-97.

2. Handbook of Service Instructions, NAVAIR 16-30ARC-51, Section IV, pages 4-1 to 4-75.

NOTETAKING OUTLINE:

A. Receiver

   1. RF Preamplifier Module (1A1)

   2. Power Amplifier Module (1A6)

   3. Spectrum Generator Module (1A5)

      a. Oscillator V_1

b. Multiplier V_2

c. Amplifiers V_3 and V_4

4. First and Second IF Amplifier Module (1A2)

a. IF amplifiers Q_1 & Q_2

b. Second receiver mixer Q_3

c. Oscillator Q_5

d. Tunable bandpass filter FL_1

e. Third receiver mixer Q_6

f. Oscillator Q_7

5. Third IF Amplifier Module (1A3)

a. 500 kHz filter FL1

b. First IF amplifier Q_1

c. Impedance matching Q_{23}

d. Second, third and fourth 500 kHz IF amplifiers

e. AVC detector CR_5 and CR_6

f. Audio amplifiers Q_{10}, Q_{11}, Q_{12}

g. AVC detectors CR_7 and CR_8

h. AVC compensator Q_8

i. AVC amplifiers Q_5, Q_6, and Q_7

j. Negative AVC amplifier Q_9

k. Squelch circuits

l. Audio gate CR_{18}

6. Modulation and Audio Module ($1A_4$)

Transmitter

. Modulator and Audio Module ($1A_4$)

a. Mike input transformer (T_1)

b. Audio amps. Q_1, Q_2, and Q_3

c. Audio transformer T_2

d. Modulation amps. Q_4 and Q_5

e. Modulation transformer T_3

. First and Second IF Amplifiers ($1A_2$)

a. Oscillator Q_7

b. Third receiver mixer Q_6

c. Tunable bandpass filter

d. Oscillator Q_5

e. First transmitter mixer Q_4

f. First and second IF amps. Q_1 and Q_2

3. Spectrum Generator ($1A_5$)

4. RF Preamplifiers ($1A_1$)

5. Power Amplifier ($1A_6$)

C. Guard Receiver

1. RF Amp. Q_1 and Q_2

2. Mixer Q_3

3. Oscillator Q_4

4. First IF Q_5

5. Crystal Filter FL_1

6. IF Amps. Q_6, Q_7, Q_8 and Q_9

7. Detector Q_{10}

8. AVC Amp. Q_{11}

9. Audio Gate CR_2

10. Noise Amps. Q_{13} and Q_{15}

11. Noise Detector CR_8 and CR_9

12. Squelch Circuit Q_{17} and Q_{18}

13. Squelch Trigger Q_{19} and Q_{20}

14. RF AGC Amp. Q_{12}

D. Frequency Synthesis

1. Calculate spectrum generator frequency.

2. Calculate oscillator Q_5 frequency

3. Calculate oscillator Q_7 frequency (Transmit)

4. Calculate oscillator Q_7 frequency (Receiv

NOTETAKING SHEET 4.7.1N

UHF TRANSMITTER CIRCUIT ANALYSIS

REFERENCES:

1. Basic Electronics, Vol. 2, NAVPERS 10087-C, pages 88-97.

2. Handbook of Service Instructions, NAVAIR 16-30ARC-51, Section IV, pages 4-28 to 4-38.

NOTETAKING OUTLINE:

A. First & Second IF Amplifier (1A2)

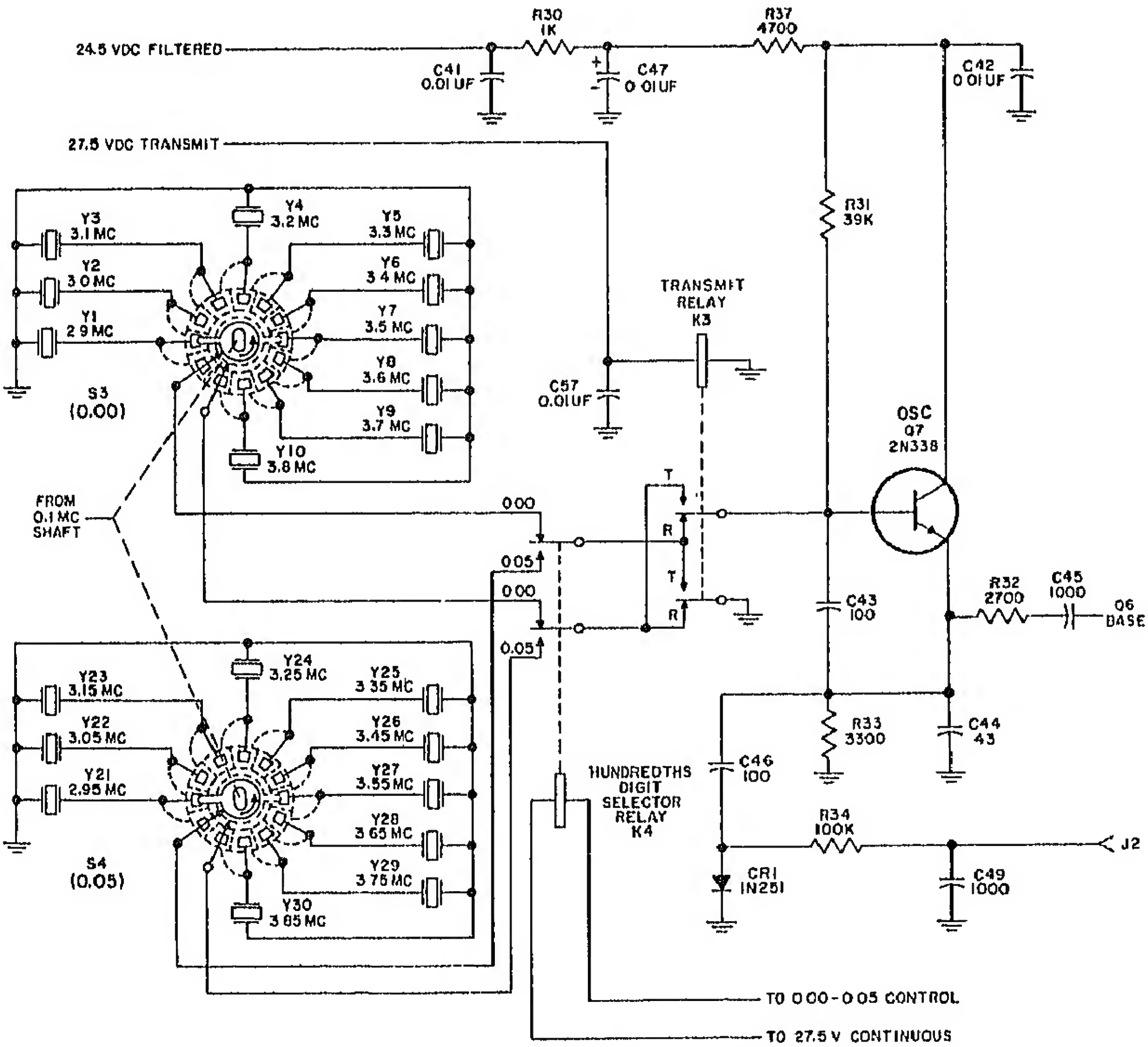


Figure 1 First and Second IF Amplifier 1A2 (RT-743/ARC-51A) 2.90- to 3.85-MHz Oscillator, Simplified Schematic Diagram.

1. 2.9 to 3.85 MHz Oscillator Q7

2. Third Receiver Mixer Q6

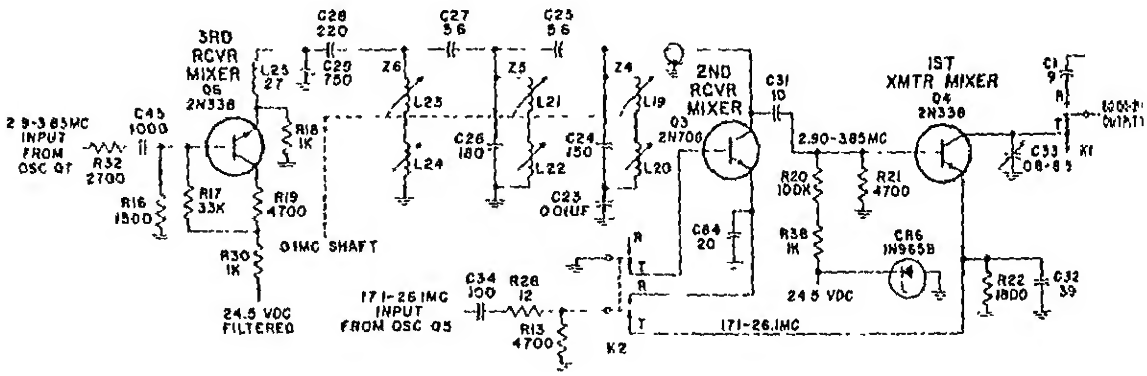


Figure 2 Third receiver mixer Q6 & Bandpass filters

3. Tunable Bandpass Filter Z4, Z5, & Z6

4. 17.1 to 26.1 MHz Oscillator Q5

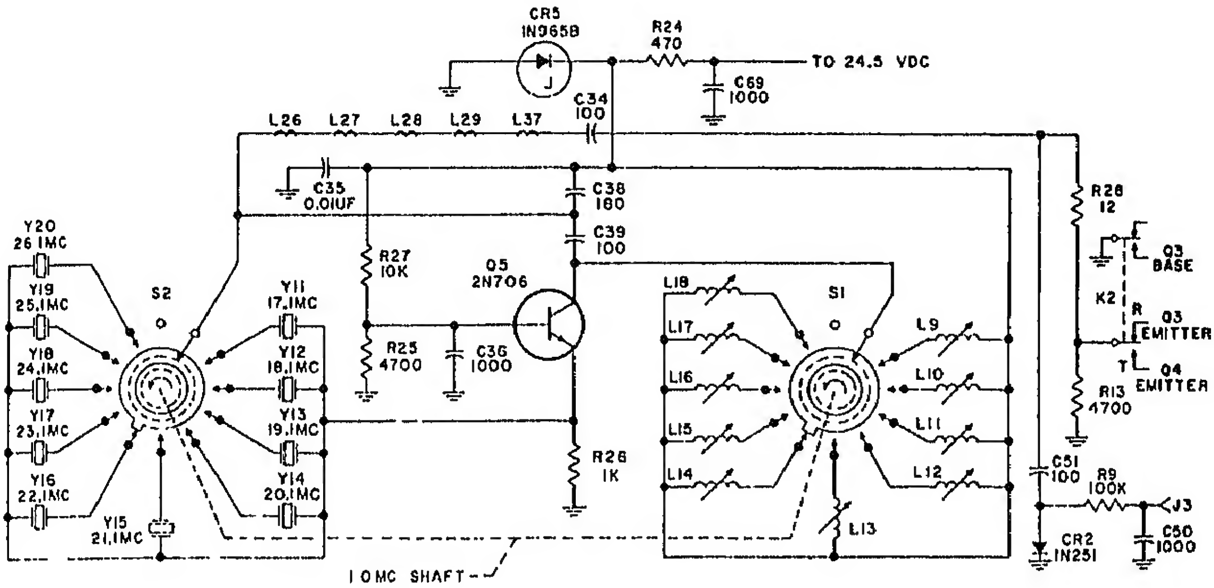


Figure 3 17.1 to 26.1 MHz Oscillator Q5

5. First Transmitter Mixer Q4 (Refer to figure 2)

6. IF amplifiers Q1 & Q2

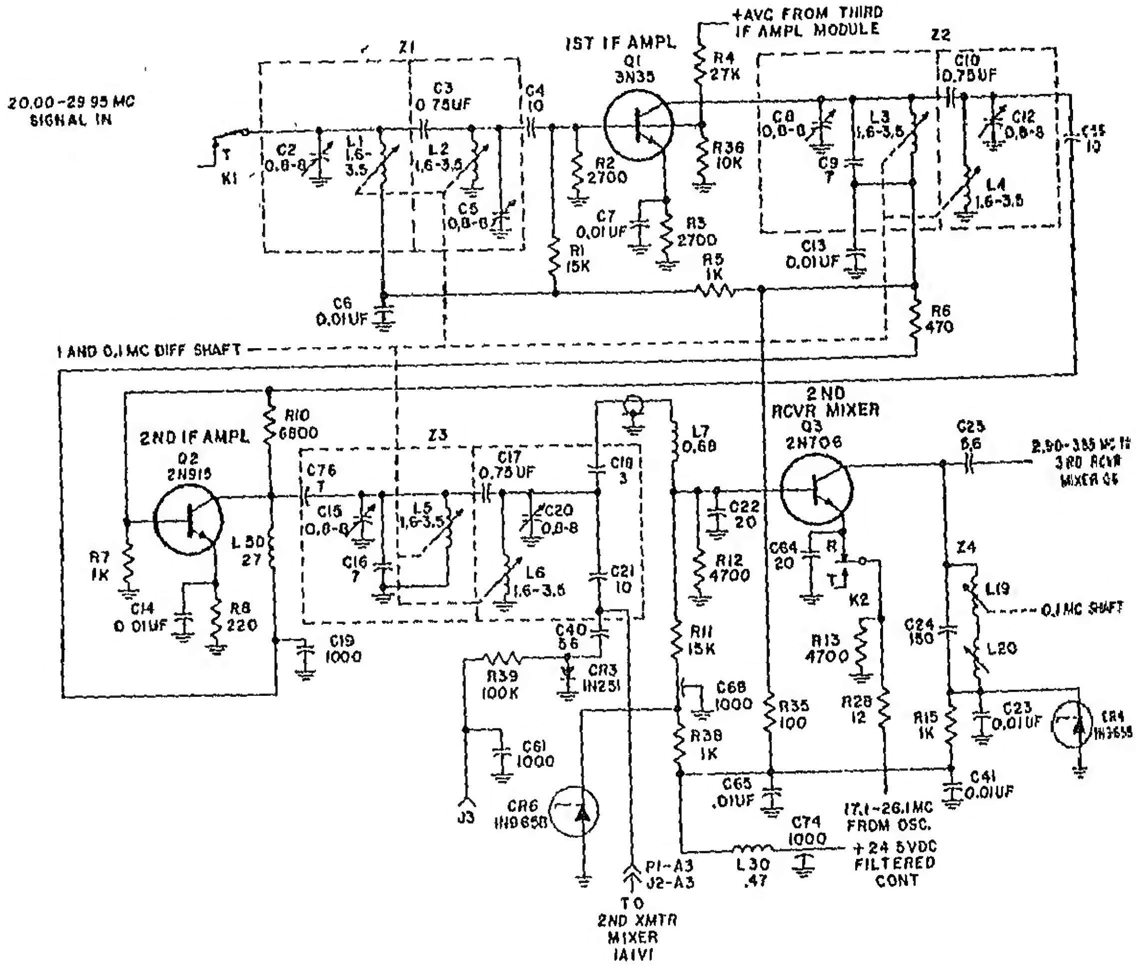


Figure 4

First and Second IF Amplifier 1A2 (RT-743/ARC-51A), IF Amplifiers and Second Receiver Mixer Circuits, Simplified Schematic Diagram

B. Spectrum Generator Module (1A5)

1. Oscillator V1

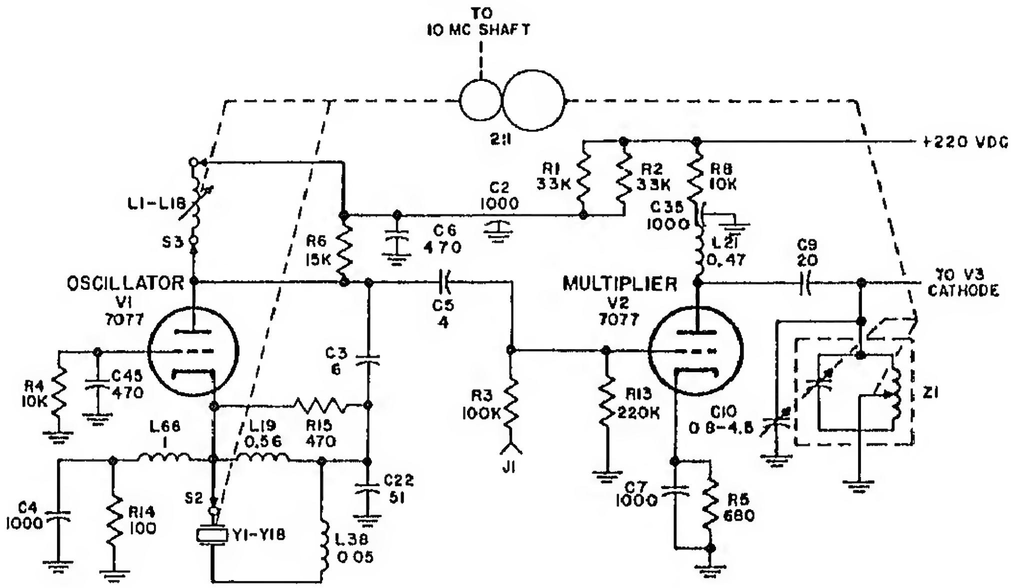


Figure 5 Oscillator V1

2. Multiplier V2

3. Amplifiers V3 & V4

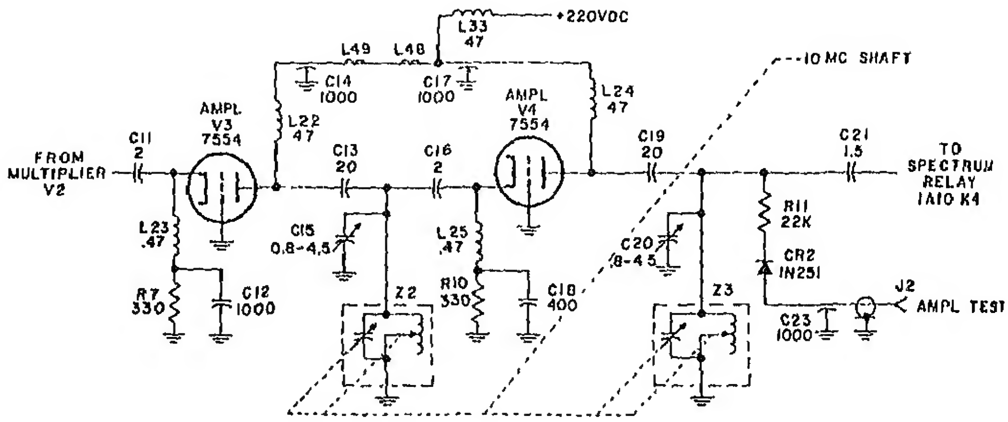


Figure 6 Amplifiers V3 & V4

4. Spectrum Generator Relay K4

C. Receiver RF Preamplifier Module (1A1)

1. Second Transmitter Mixer

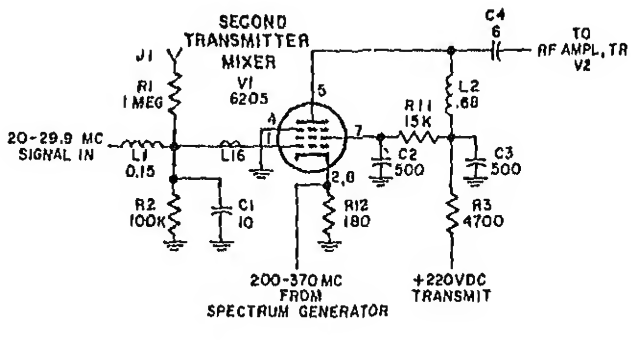


Figure 7 Second Tx Mixer

2. Amplifiers V2 & V3

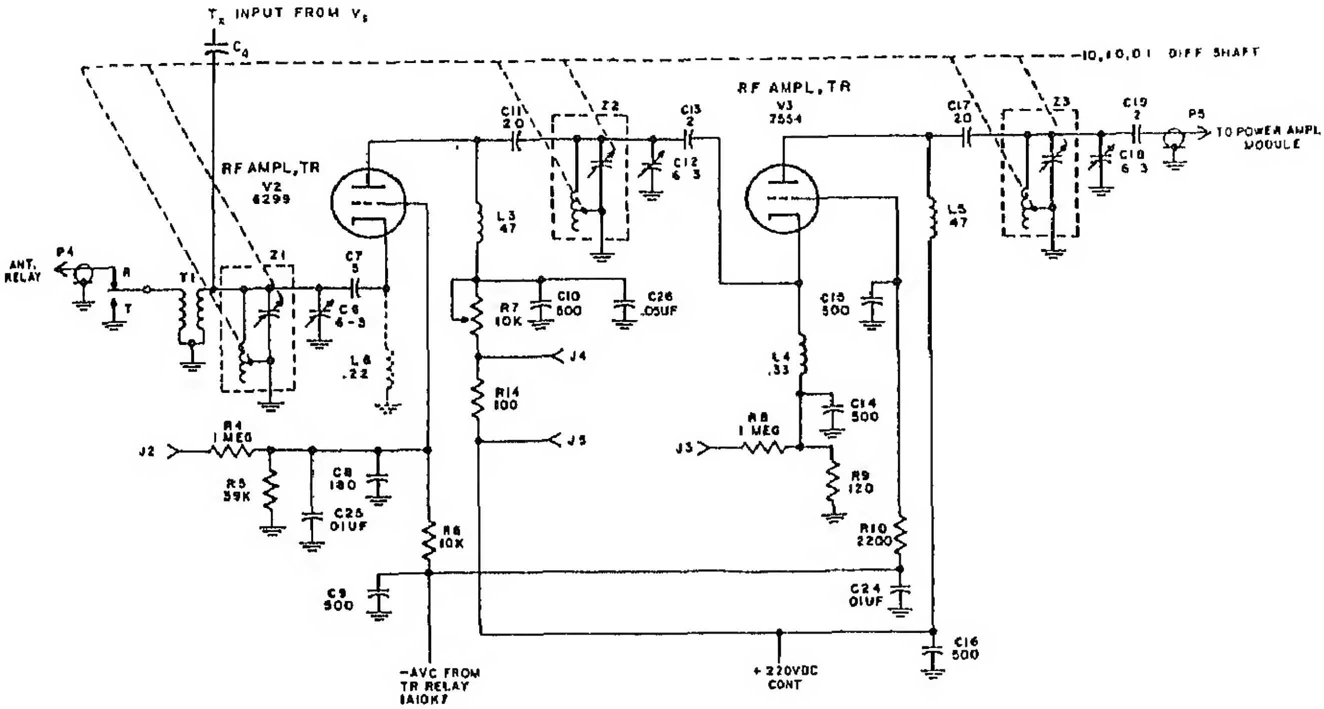


Figure 8 RF Amplifiers V2 & V3

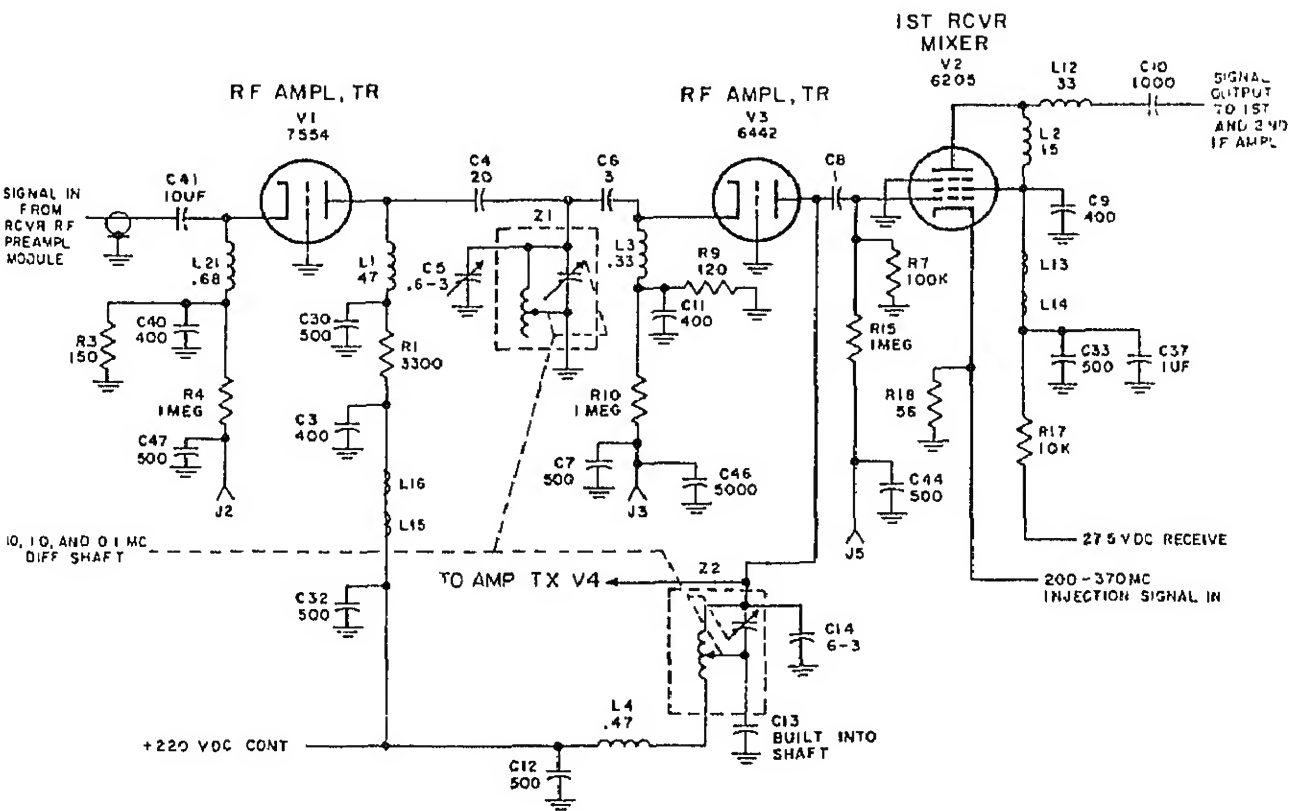


Figure 9 Power Amplifier 1A6

D. Power Amplifier Module (1A6)

1. RF amplifiers V1 & V3

2. RF amplifier, transmitter V4

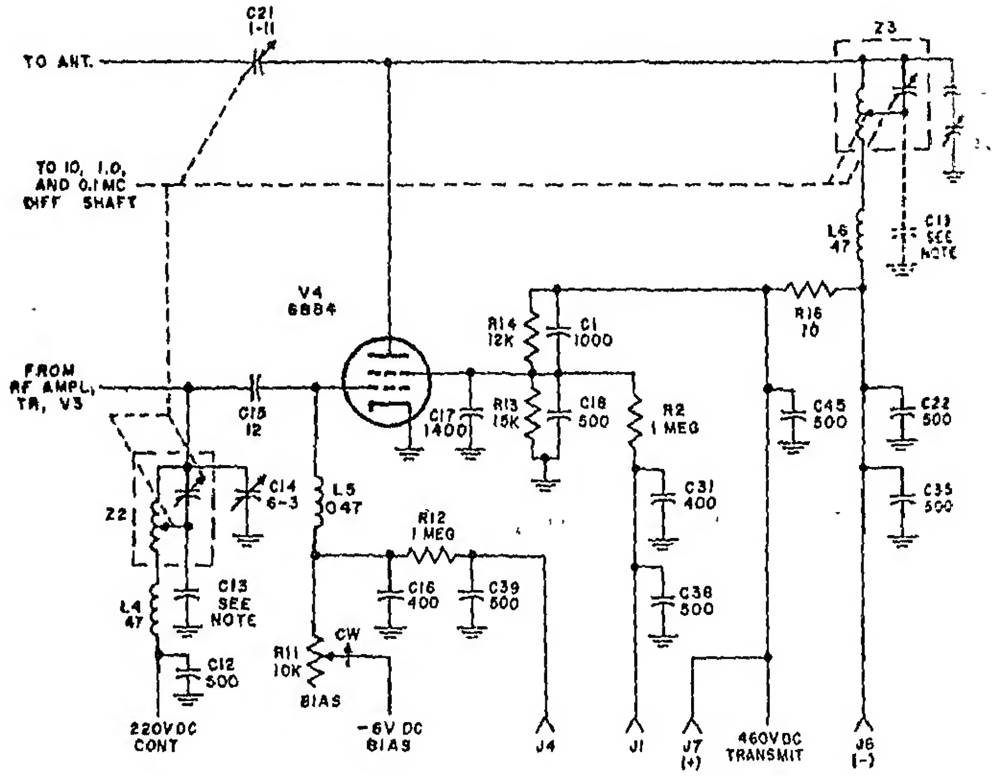


Figure 10 Transmitter RF Amplifier V4

E. Modulator and Audio Module (1A4)

1. Microphone

2. Audio amplifiers Q1, Q2, & Q3

3. Audio amplifiers Q4 & Q5

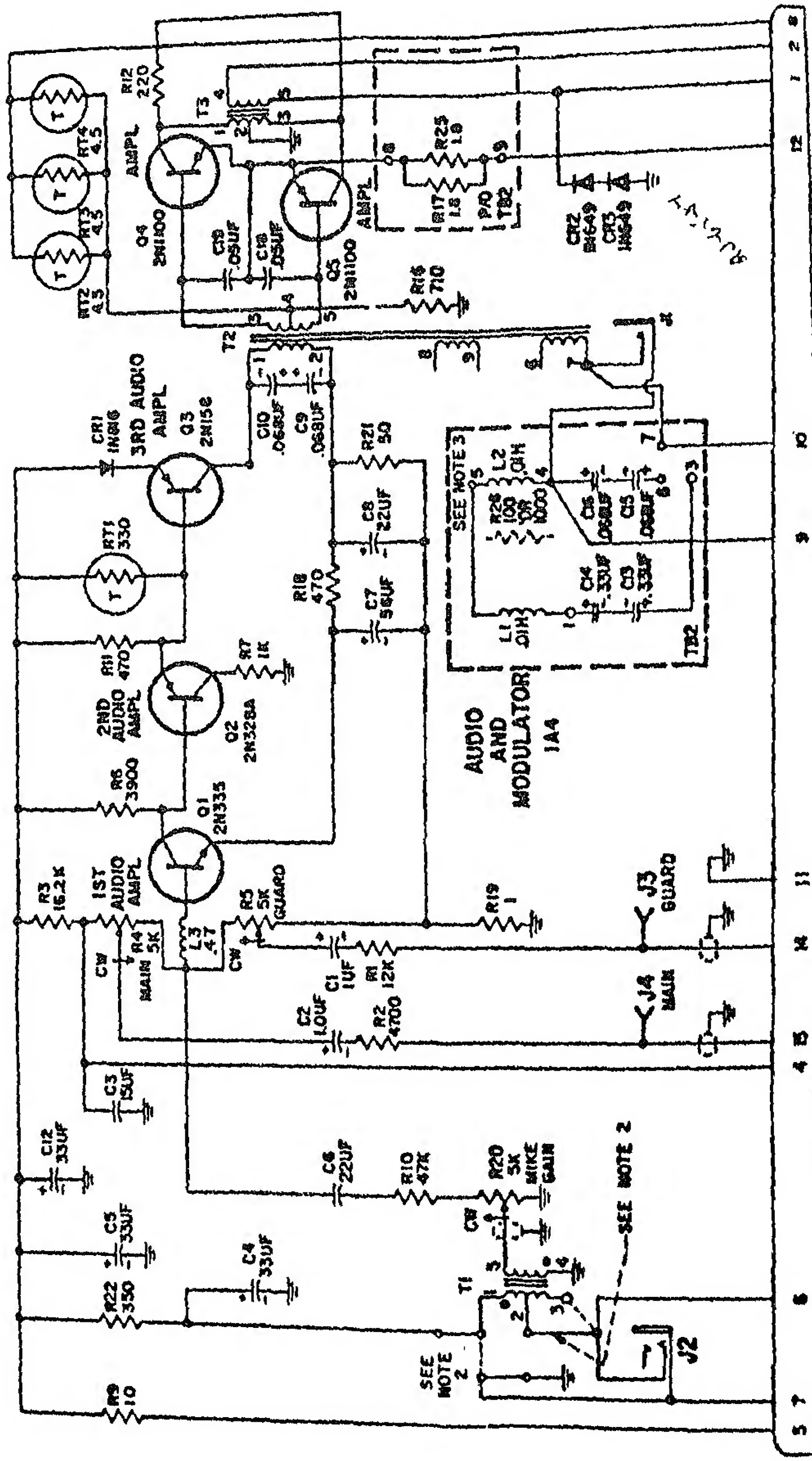


Figure 11 - Modulator & Audio Module (1A4)

?. Antenna Relay and Sidetone

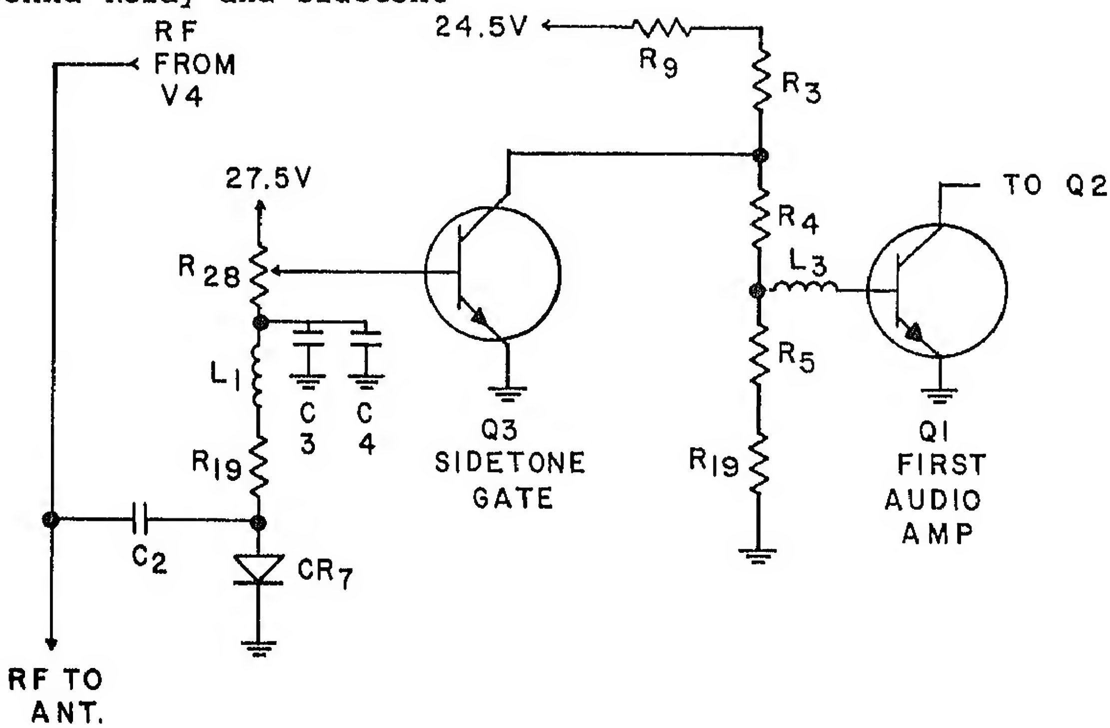


Figure 12 Antenna Relay and Sidetone Gate

NOTETAKING SHEET 4.8.1N

UHF RECEIVER CIRCUIT ANALYSIS

REFERENCES:

1. Basic Electronics, Vol. 2, NAVPERS 10087-C, pages 88-97.

2. Handbook of Service Instructions, NAVAIR 16-30ARC-51-2, Section IV, pages 4-4 to 4-21.

NOTETAKING OUTLINE:

A. Receiver RF Preamplifier Module (1A1)

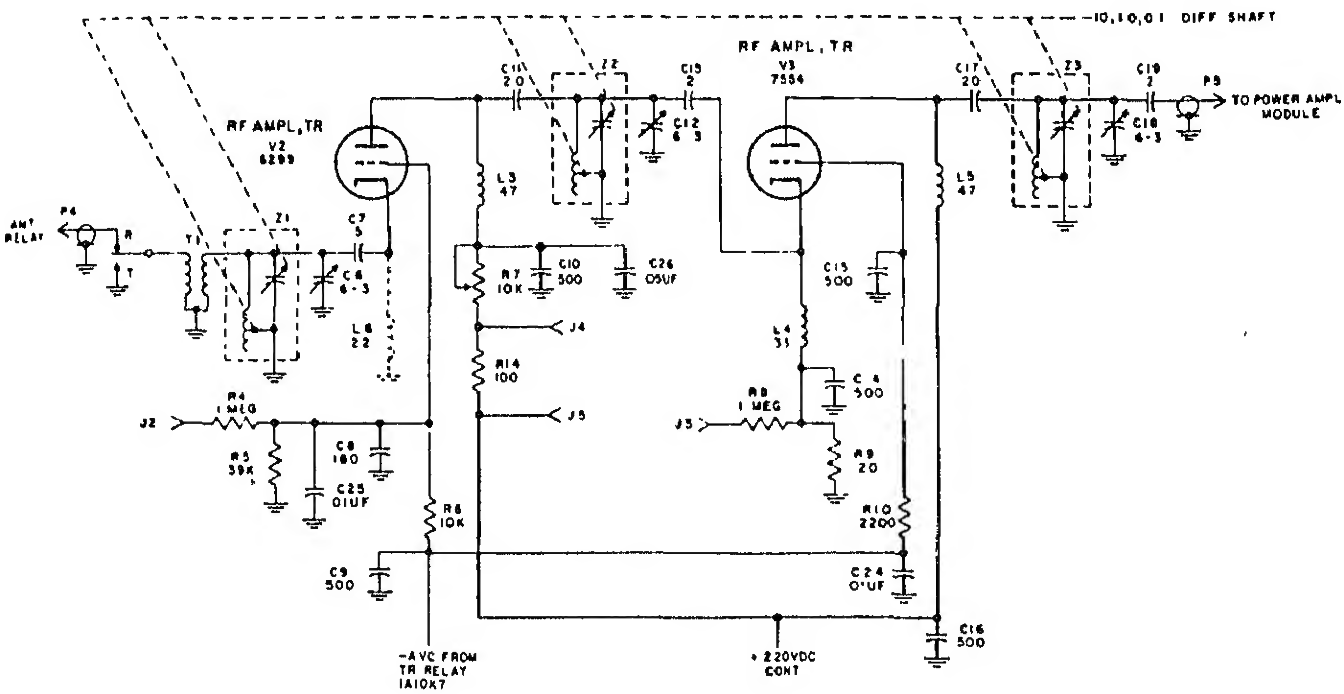


Figure 1 Receiver RF Preamplifier Module 1A1

B. Power Amplifier Module (1A6)

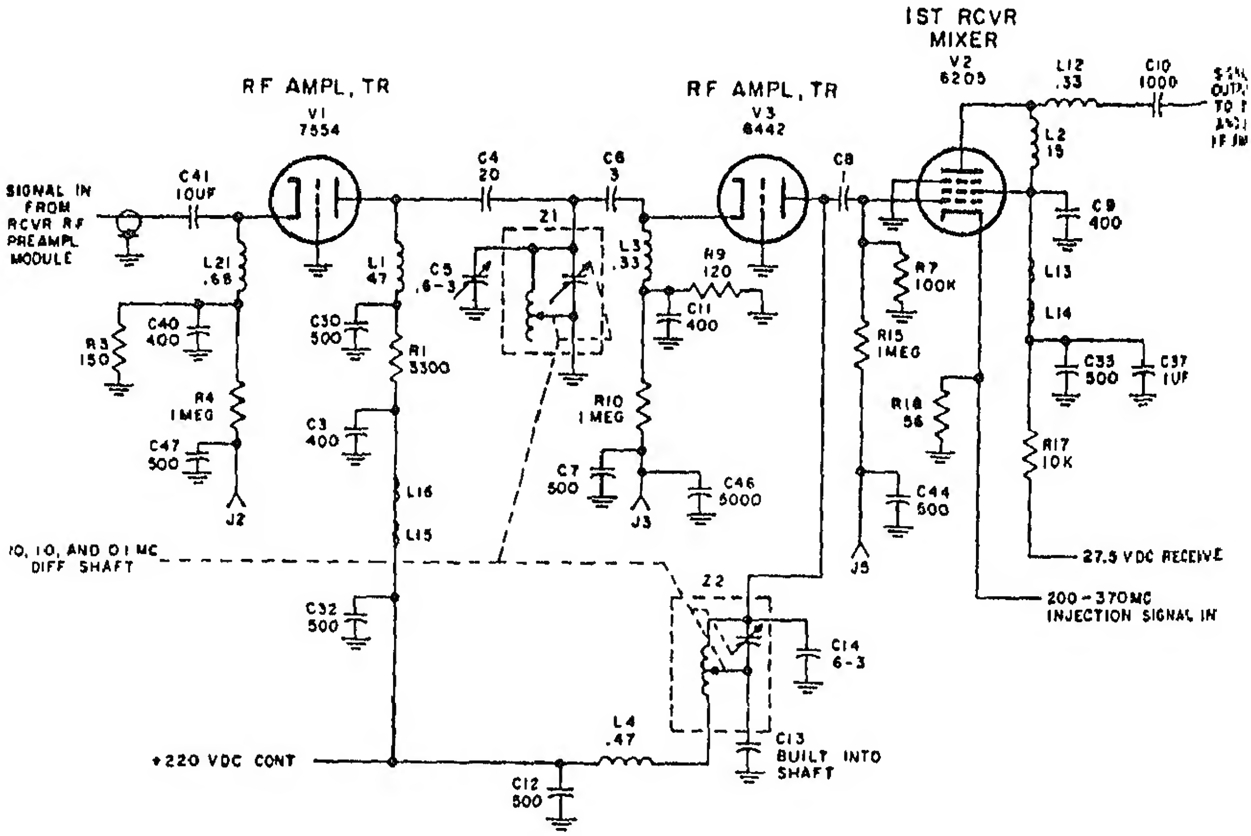


Figure 2 Power Amplifier Module 1A6

1. Input to RF Amp. V_1.

2. RF Amp V_3.

3. First Receiver Mixer V2.

C. Spectrum Generator Module (1A5)

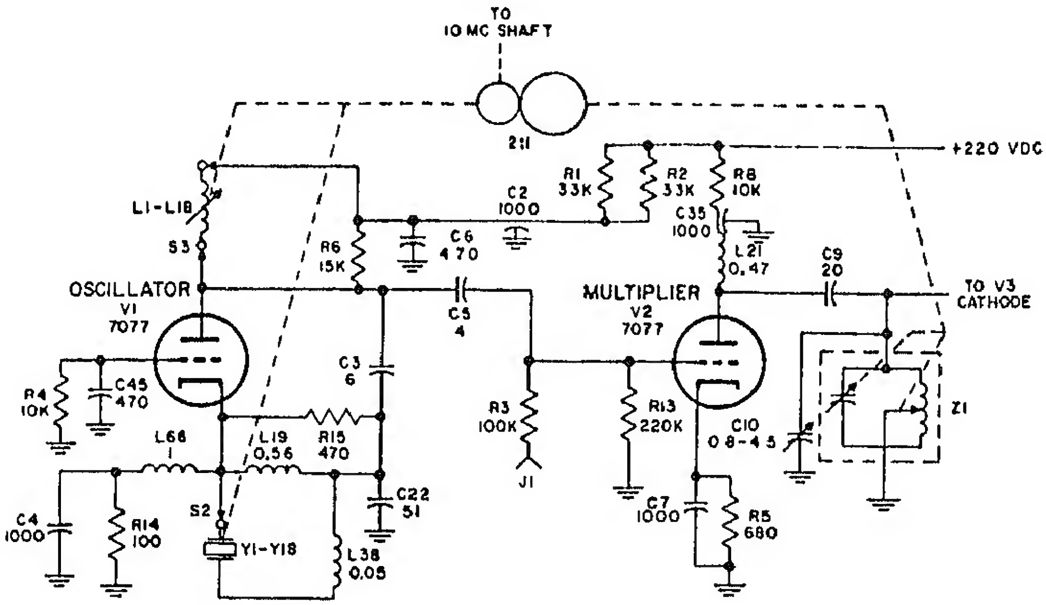


Figure 3 Spectrum Generator Module 1A5

1. Oscillator V1

2. Multiplier V2

3. Amplifiers V3 & V4

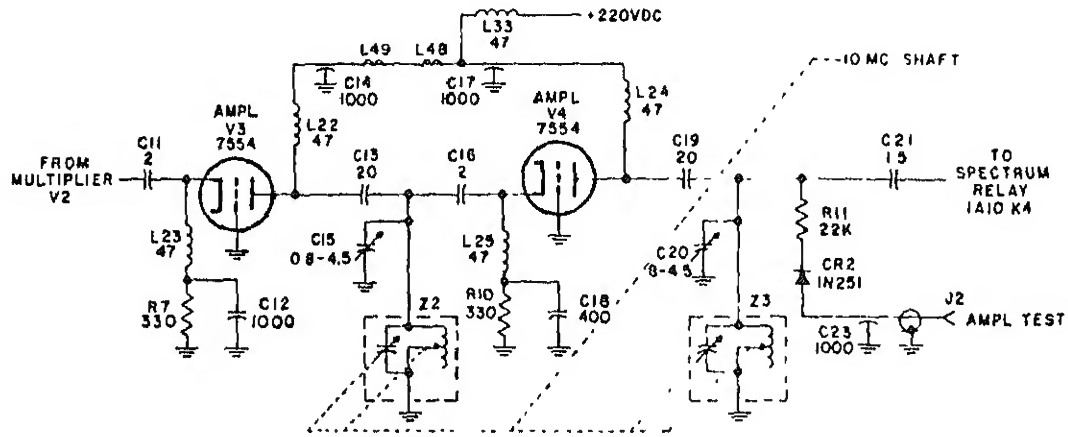


Figure 4 Spectrum Generator Amplifiers V3 & V4

D. First and Second IF Amplifier Module 1A2

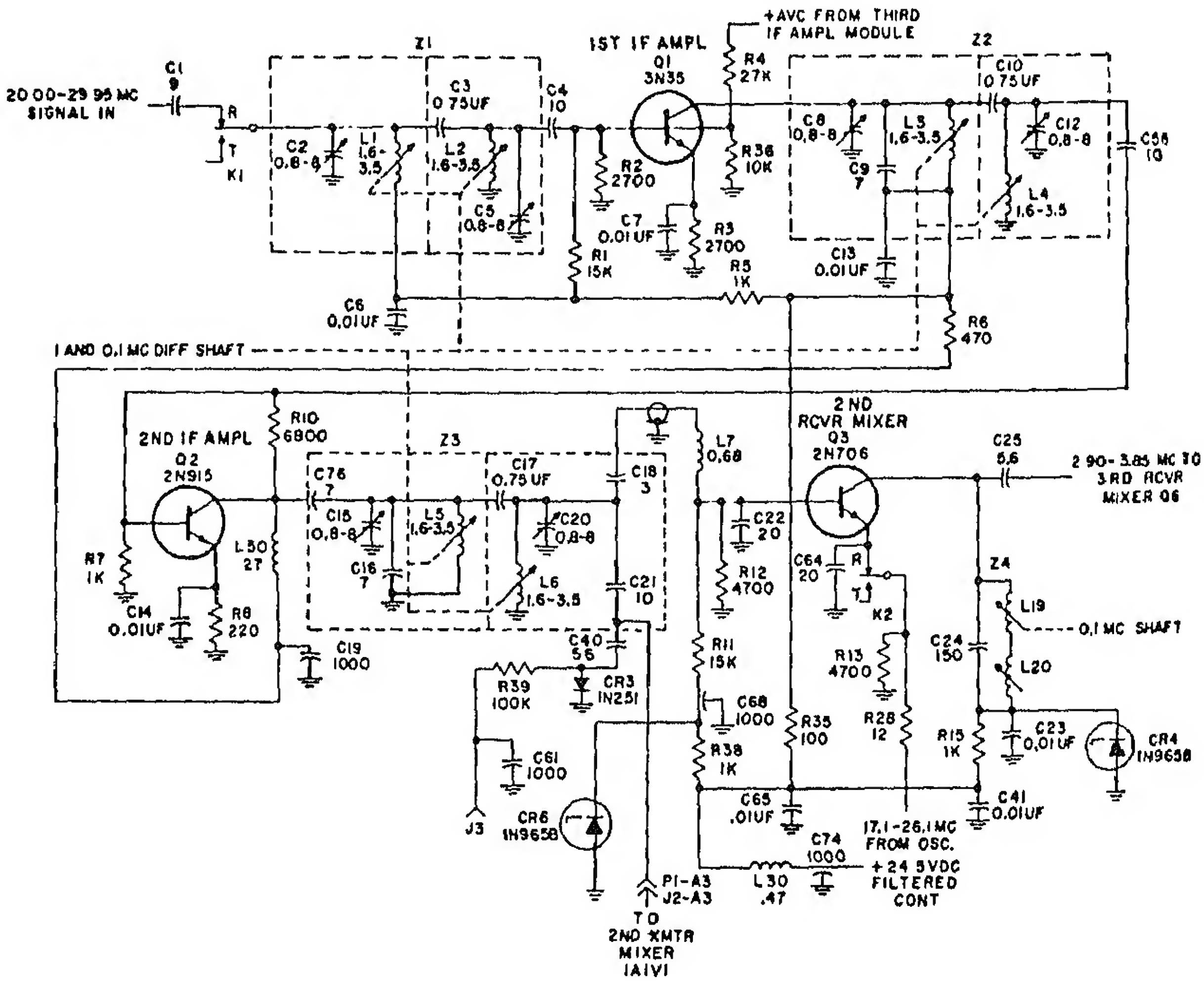


Figure 5 First & Second Amplifier Module 1A2

1. Transformers Z1, Z2, and Z3

2. Amplifiers Q1 & Q2

3. Second Receiver Mixer Q3

4. Second Oscillator Q5 17.1 - 26.1 MHz

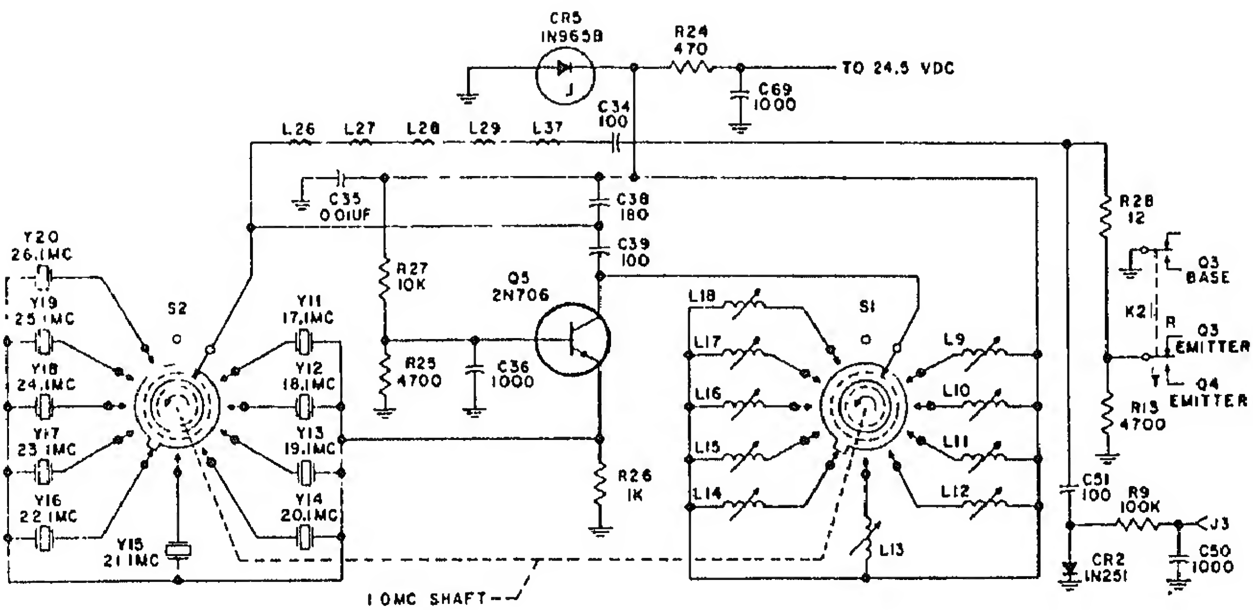


Figure 6 Second Oscillator Q5

5. Third Receiver Mixer Q6

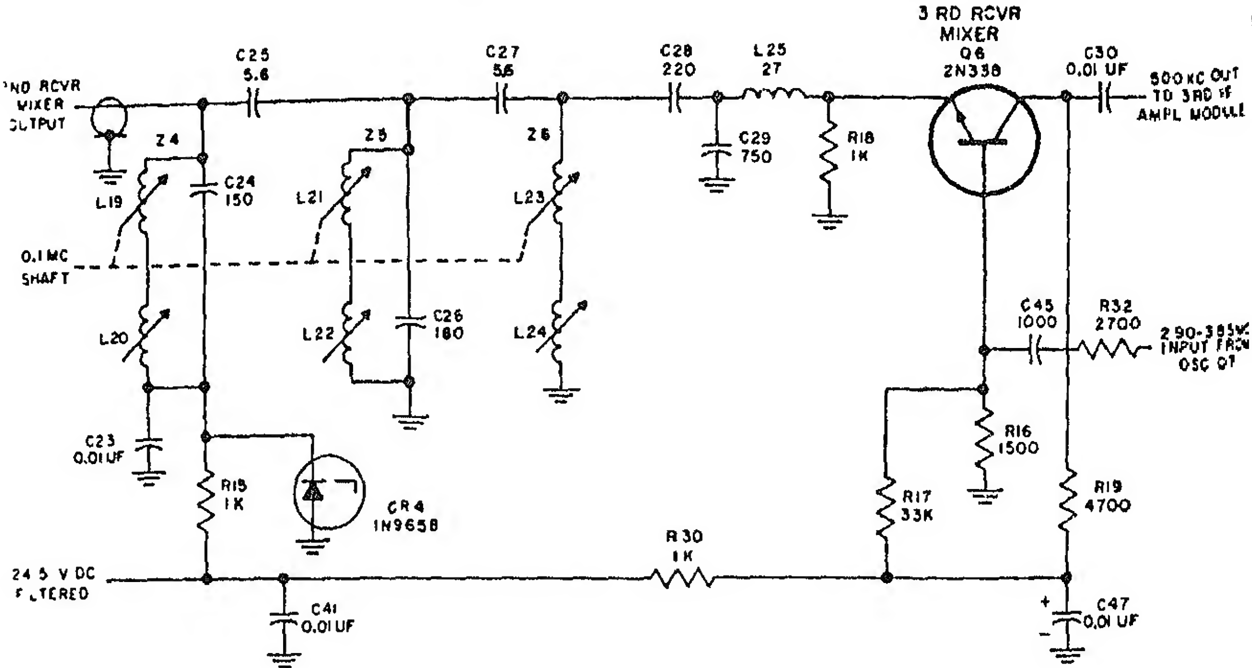


Figure 7 Second Oscillator Q5

6. Third Oscillator Q7 2.9 - 3.85 MHz

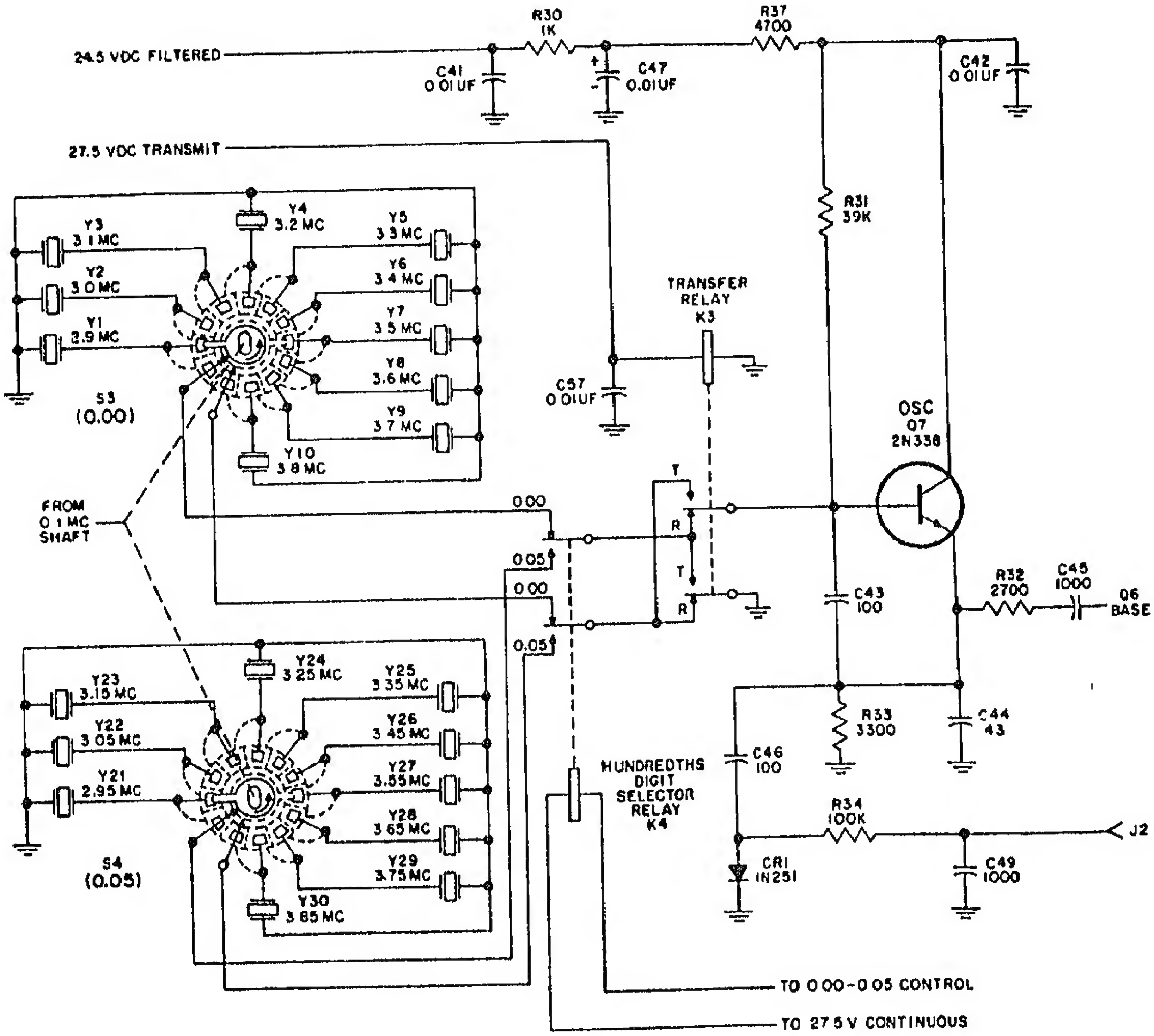


Figure 8 Third Oscillator Q7

E. Third IF Amplifier Module 1A3

1. IF Amps. Q1, Q2, Q3, and Q4

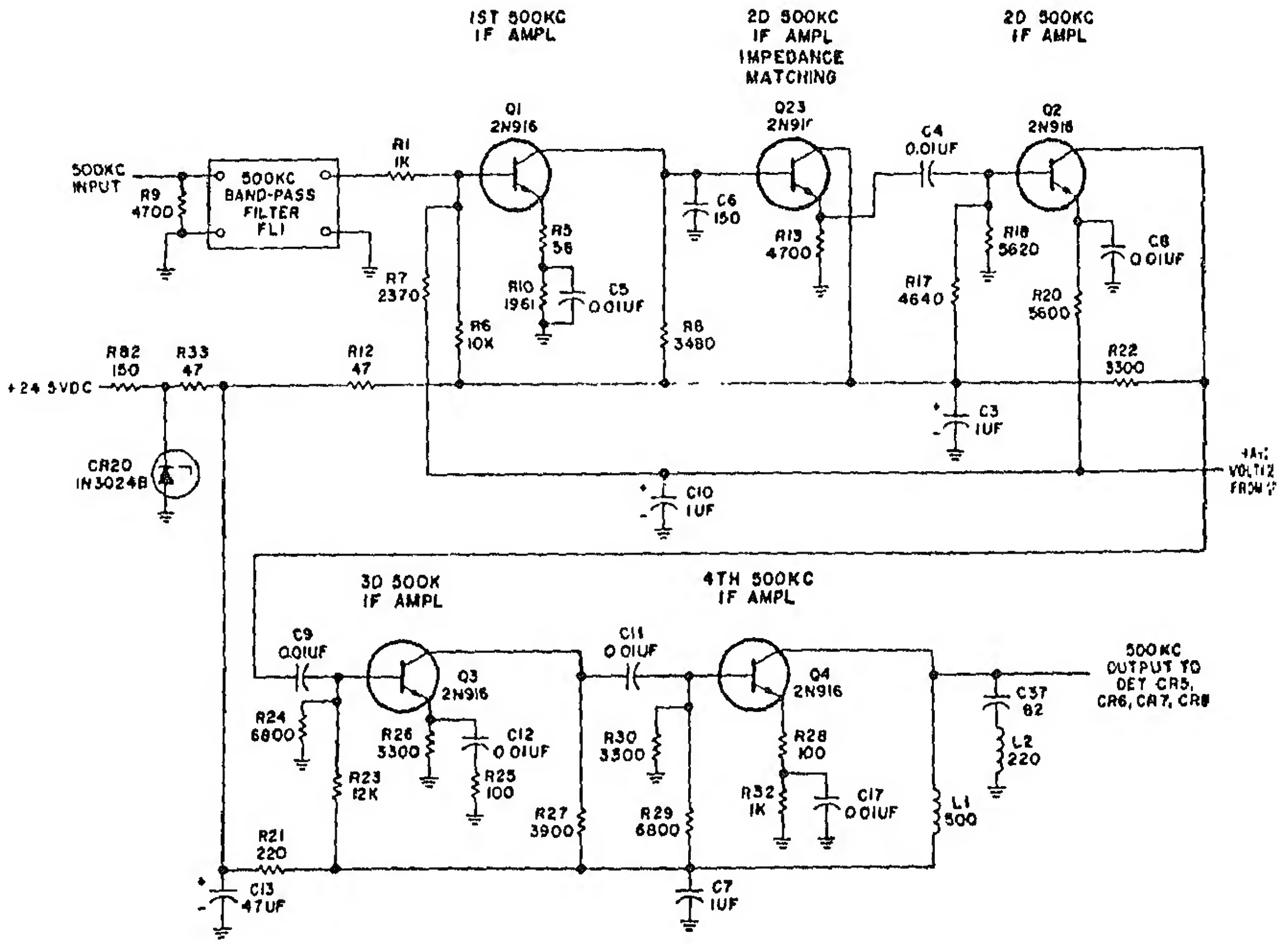


Figure 9 Third IF Amplifier Module 1A3

2. AVC Detectors CR5 and CR6

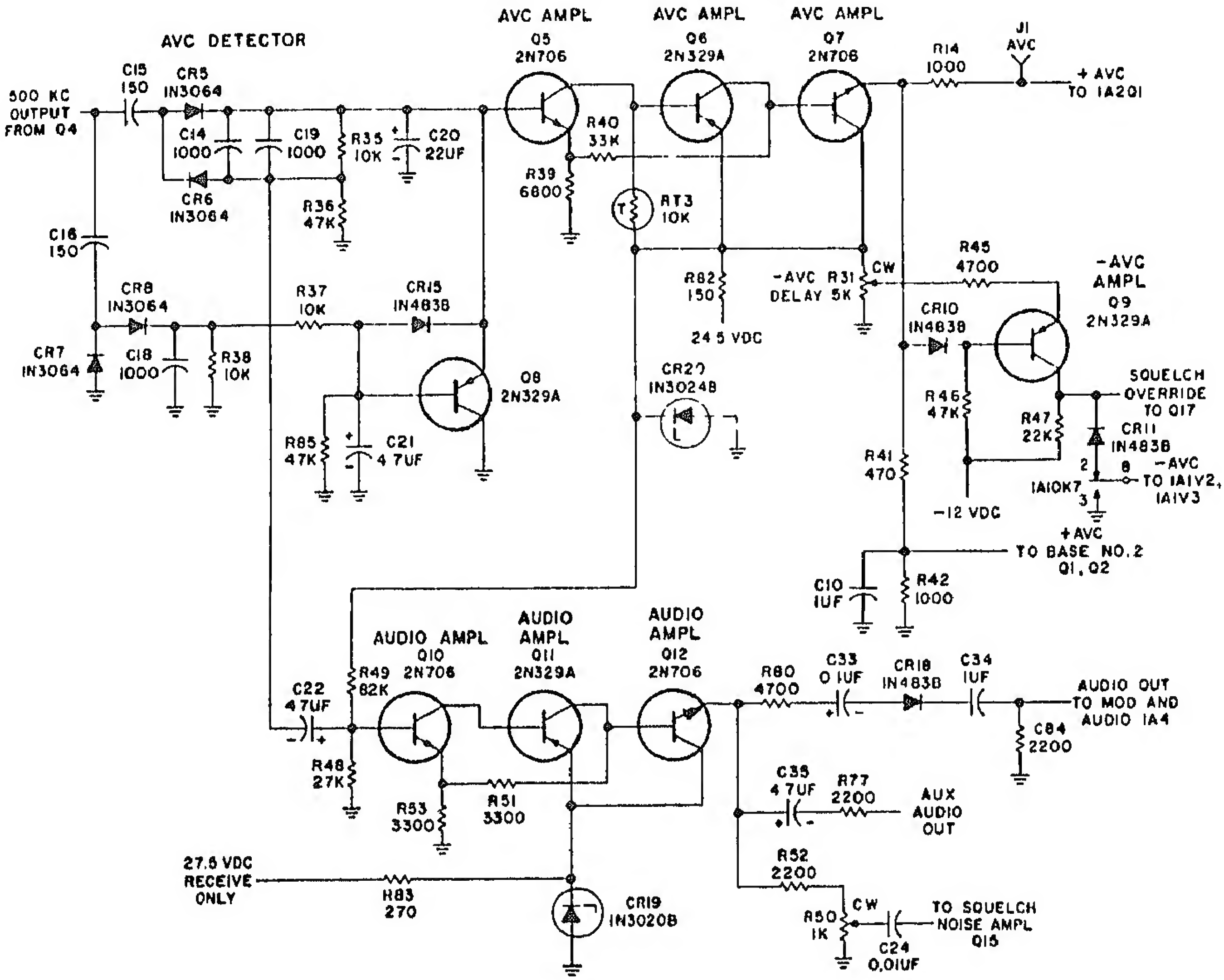


Figure 10 Third Amplifier, AVC Detector and Audio Circuits

3. Audio Amplifiers Q10, Q11 and Q12

4. Audio Gate CR18

F. Modulator and Audio Module 1A4

1. First Audio Amplifier Q1

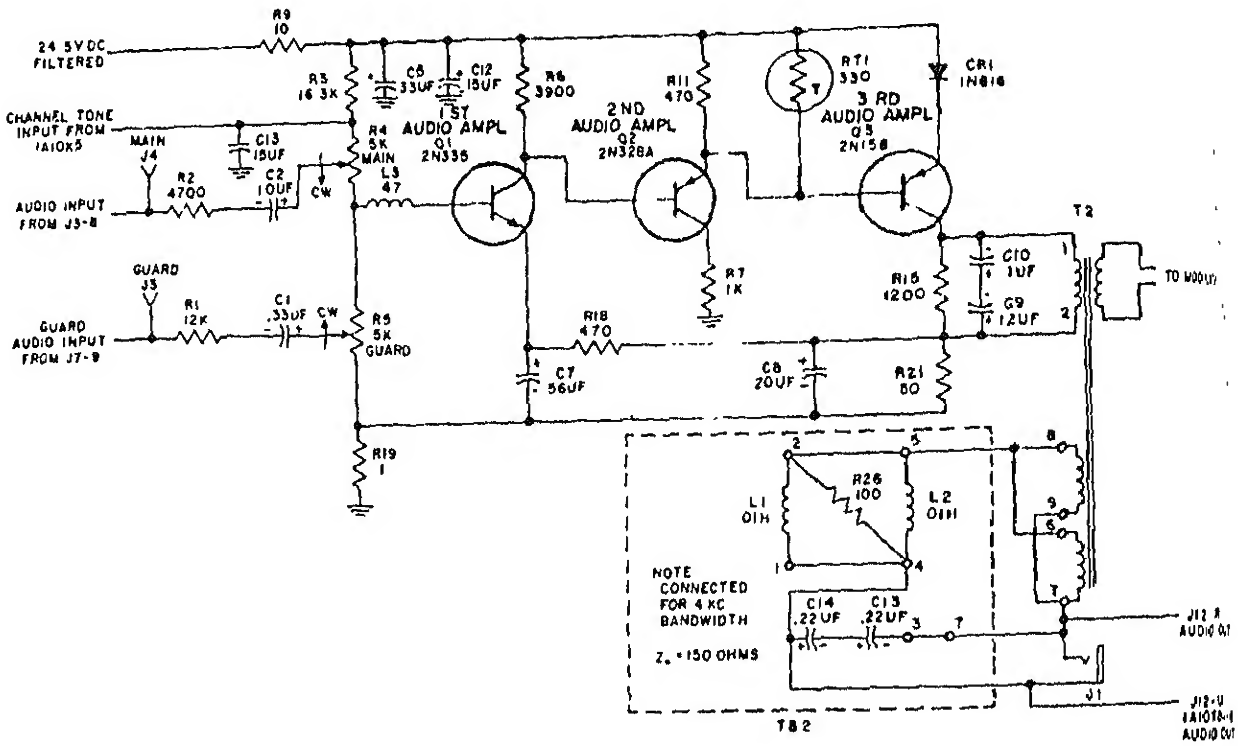


Figure 11 Audio Amplifier Circuits

2. Direct-Coupled Amps. Q2 and Q3

G. AVC in Module 1A3 Refer to figure 10a next page.

1. AVC Detector CR5

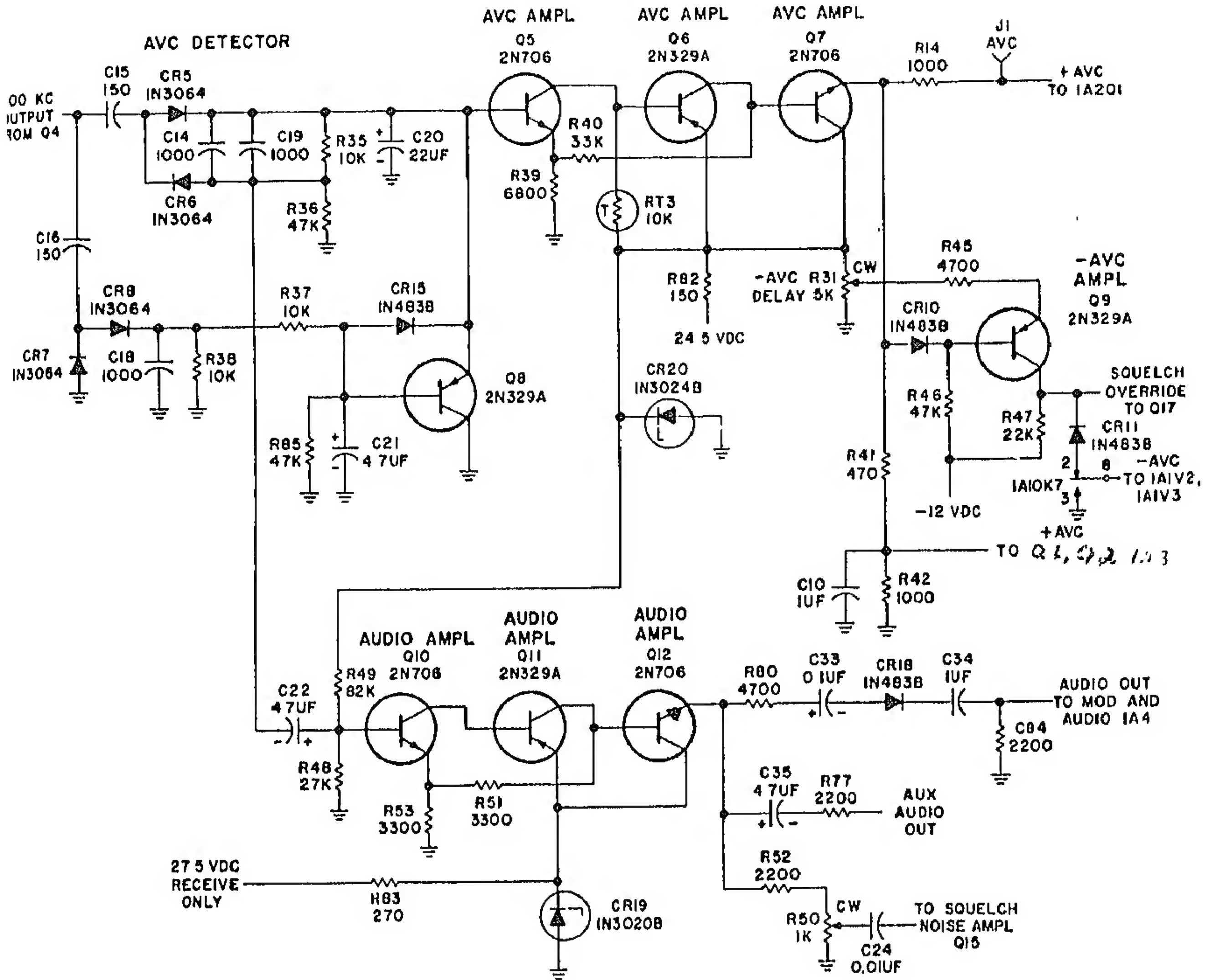


Figure 10a Third Amplifier, AVC Detector and Audio Circuits

2. AVC Amps. Q5, Q6, and Q7

3. AVC Amp. Q9

4. Discharge Transistor Q8

H. Carrier-to-Noise Squelch in 1A3 Refer to figure 12 next page.

1. Squelch Noise Amp. Q13

2. Emitter Q14

3. Squelch Noise Amp. Q15

4. Emitter Follower Q16

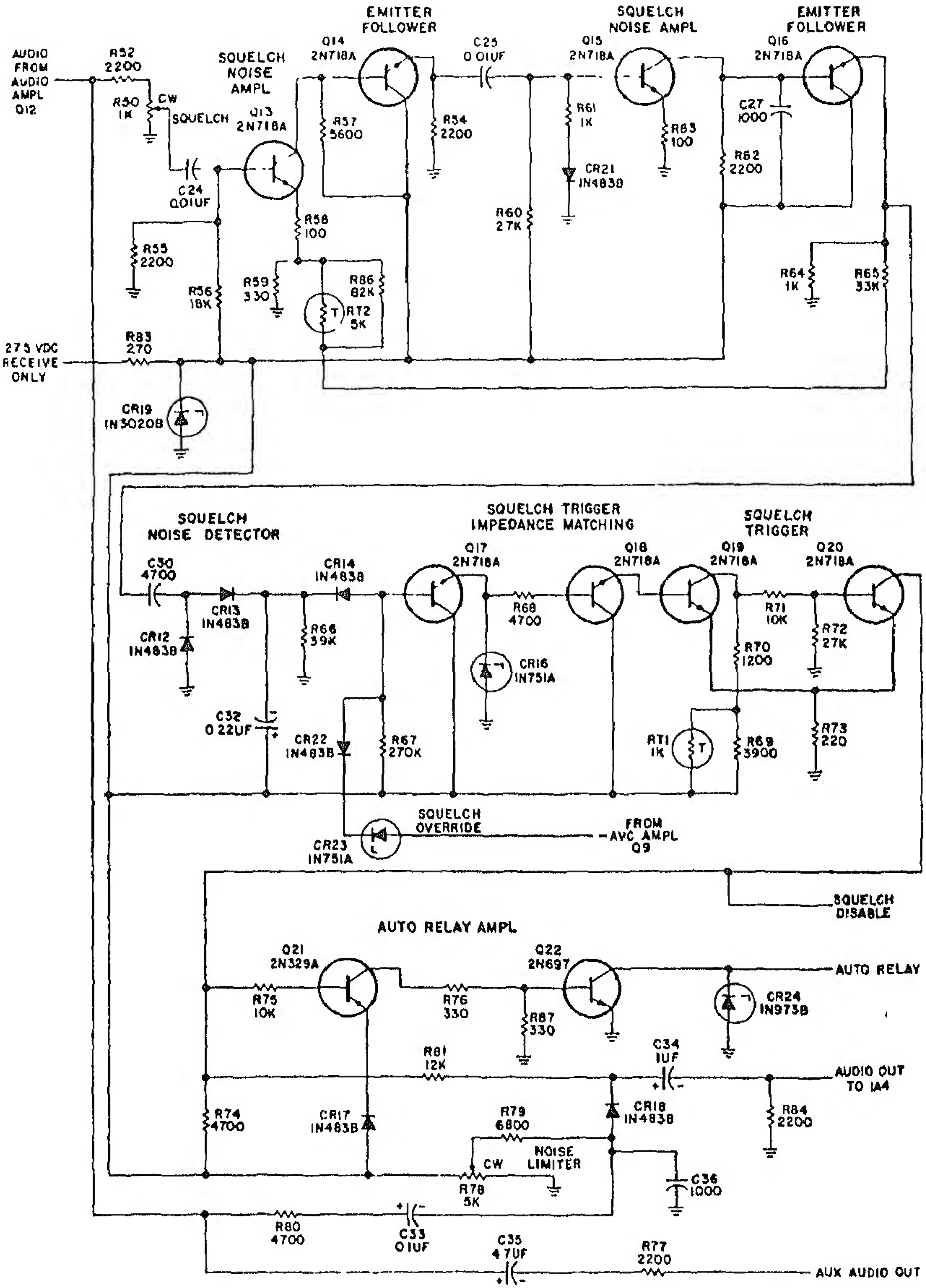


Figure 12   1A3 Module Squelch Circuits

5. Noise Detector CR12 and CR13

6. Emitter Follower Q17

7. Emitter Follower Q18

8. Squelch Trigger Q19 and Q20

9. Audio Gate CR18

10. No Audio Signal in

11. Audio Relay Amp. Q21 and Q22

12. Squelch Override

NOTETAKING SHEET 4.9.1N

GUARD RECEIVERS

REFERENCES:

1. Basic Electronics, Vol. 2, NAVPERS 10087-C, pages 88-97.

2. Handbook of Service Instructions, NAVAIR 16-30ARC-51-2, Section IV, pages 4-26 to 4-28.

NOTETAKING OUTLINE:

A. RF Amplifiers

(Refer to ARC-51 guard receiver schematic)

1. RF Amplifier Q1

2. RF Amplifier Q2

3. Collectors Q1 & Q2

B. Oscillator and Mixer

1. Oscillator Q4

2. Mixer Q3

C. 20.55 MHz IF Strip

1. IF amps. Q5 to Q8

2. Crystal Filter FL1

3. IF Amp. Q9

D. Detector, Audio, Squelch, and AVC

1. Audio Detector Q10

2. AVC Amp. Q11

3. AVC

a. AVC Amp Q11.

b. RF AVC Amp Q12.

4. Audio Gate CR2

5. Squelch Control R51

6. Noise Amp Q13

7. Emitter Follower Q21

8. Noise Amp Q15

9. Emitter Follower Q16

10. Noise Detectors CR8 and CR9

11. Emitter Follower Q17

12. Emitter Follower Q18

13. Squelch Trigger Q19 and Q20.

14. With High Level Noise In

INFORMATION SHEET 4.10.1I

AUTOMATIC RADIO DIRECTION FINDING

NTRODUCTION

'o enhance your understanding of the "Automatic Radio Direction 'inding (ARDF)" lesson, this information sheet will provide you 'ith the purpose, terminology, and definitions required for your 'omprehension.

EFERENCES

.. Basic Electronics, Volume II, NAVPERS 10087-C, pages 88-97.

!. Handbook of Service Instructions, NAVAIR 16-30ARA 50-1, pages 8-21 through 8-32.

NFORMATION

. Purpose and use of the automatic radio direction finder (ARDF)

  a. The primary purpose of the ARDF is to ascertain the direction to a particular UHF radio transmitter.

  b. The primary use of the ARDF is homing.

  c. Two other uses, which are modified homing uses, are air-sea rescue and attack.

!. Terminology and definitons of terms

  a. Bearing - direction or azimuth in degrees, starting at some fixed reference point and reading in a clockwise direction from 000 to 360 degrees.

  b. True Bearing - bearing taken on a transmitter station, in a clockwise direction with respect to true north.

  c. Relative Bearing - bearing taken to a radio transmitter, in a clockwise direction with respect to the nose of the aircraft.

  d. Deviation - error in bearing caused by surrounding ferrous object(s).

  e. Variation - error caused by displacement of magnetic north from true north.

f. Homing - flying directly at a transmitter station, or having the station on a relative bearing of 000 degrees with no drift angle.

g. ARDF antenna error - error caused by the RF signal striking the metal surface of the aircraft and being reflected at a different angle to the directional antenna.

(1) Error is least noticeable at 000 and 180 degrees relative.

(2) At these points, the aircraft is symmetrical and the reflected energy from one side will cancel out the reflected energy from the other side.

h. Null - the point of minimum signal strength.

(1) More sharply defined than point of maximum signal.

(2) Used for homing.

NOTETAKING SHEET 4.10.1N

AUTOMATIC RADIO DIRECTION FINDING (ARDF)

REFERENCES:

1. Basic Electronics, Vol. II, NAVPERS 10087-C, pages 88-97.

2. Handbook of Service Instructions, NAVAIR 16-30ARA 50-1, pages 8-21 to 8-32.

NOTETAKING OUTLINE:

A. Purpose and Uses of ARDF

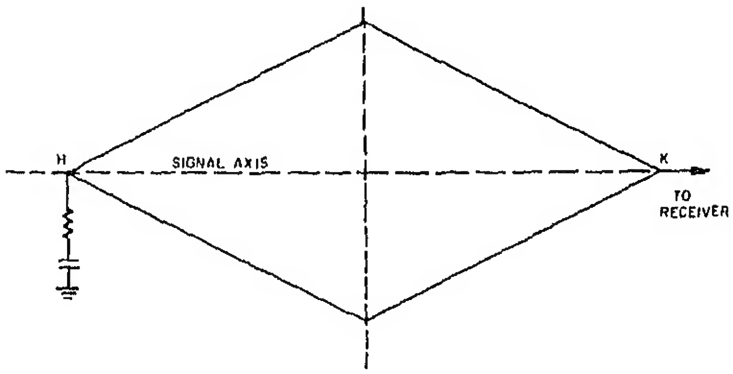
   1. Purpose

   2. Uses

B. Terminology and Definitons

C. External Equipment

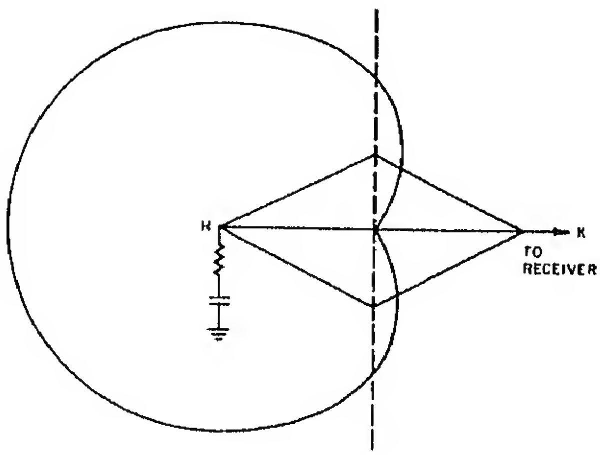
1. General Information



Basic Rhombic Antenna

Figure 1

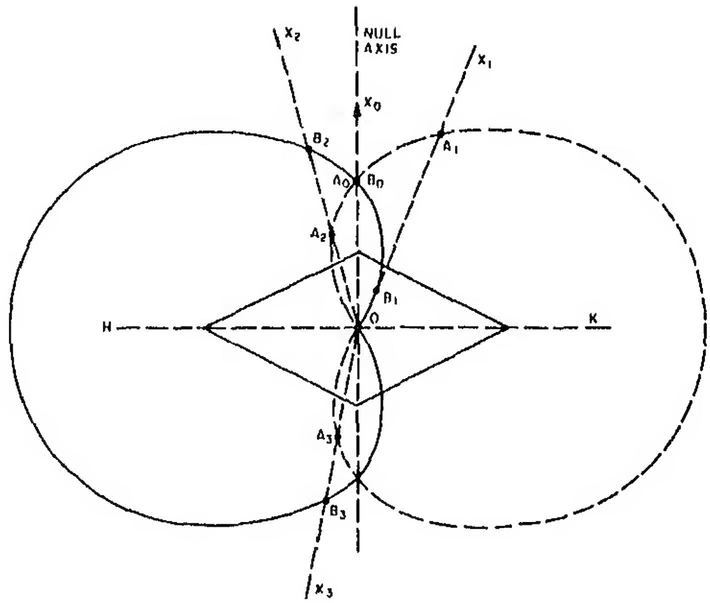
2. Antenna



Cardioid Pattern

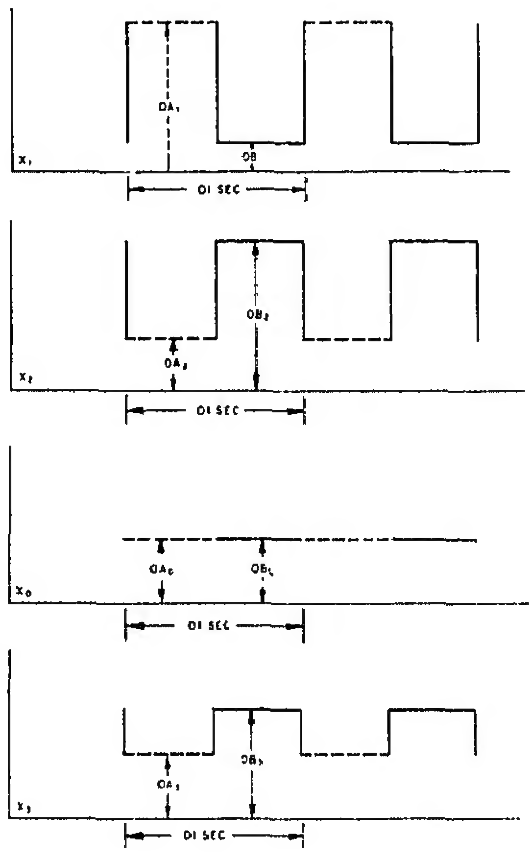
Figure 2

3. Antenna ADF Pattern



Antenna ADF Pattern

Figure 3



ADF Signal Paths

Figure 4

4. Receiver

D. Electronic Control Amplifier

1. 155 Hz Oscillator, Q11 & Q12

2. 400 Hz 115 Va-c supply voltage

3. Clipper, CR1 & CR2

4. Emitter Follower, Q1

5. Preamplifier, Q2

6. Synchronous Filter, Q3 & Q4

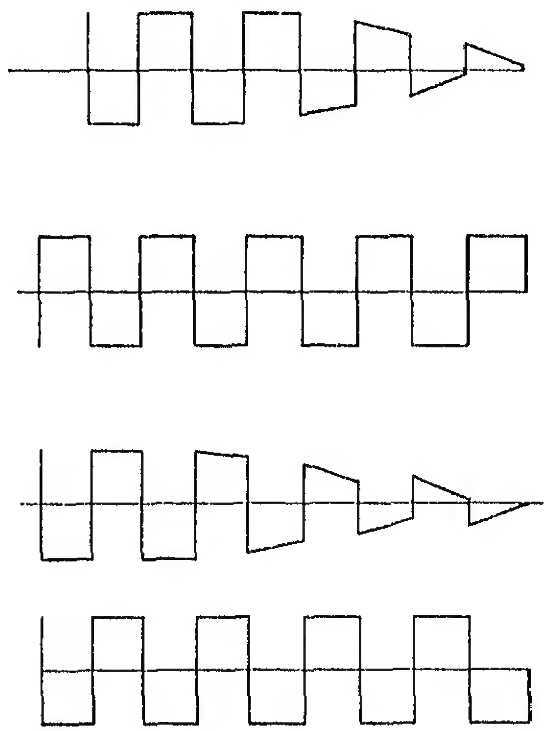


Figure 5 Filtered square wave

7. Audio Amplifier Section, Q5, Q6, Q7 & Q8

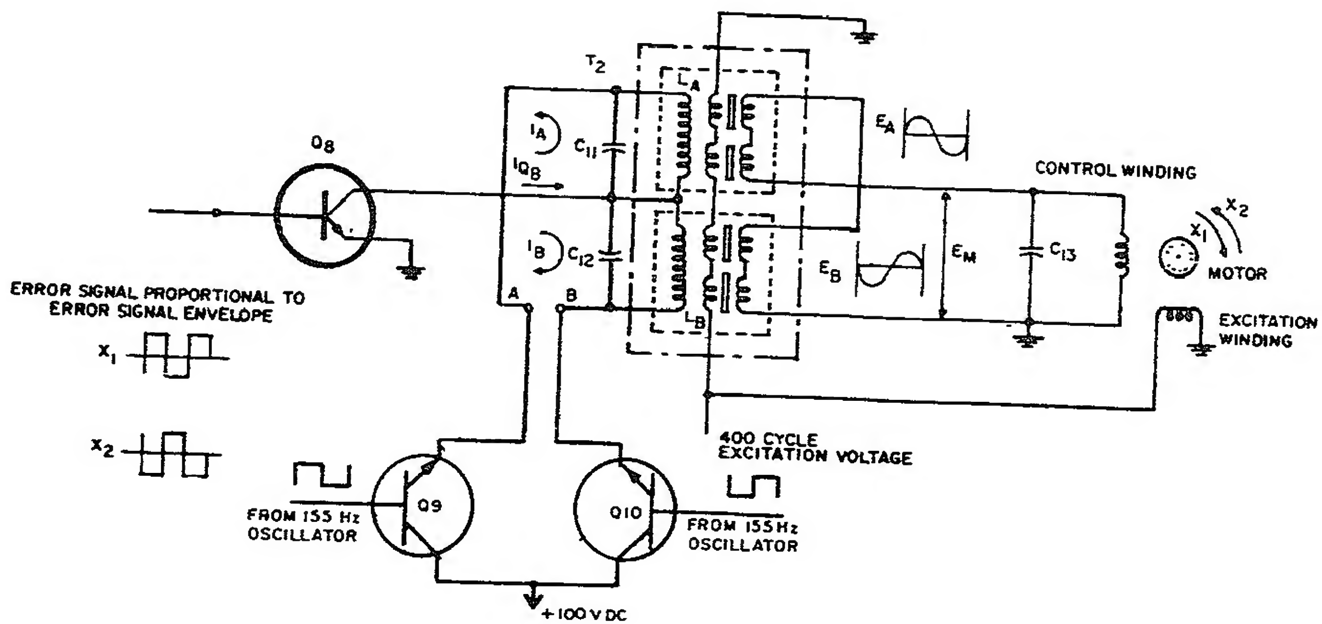
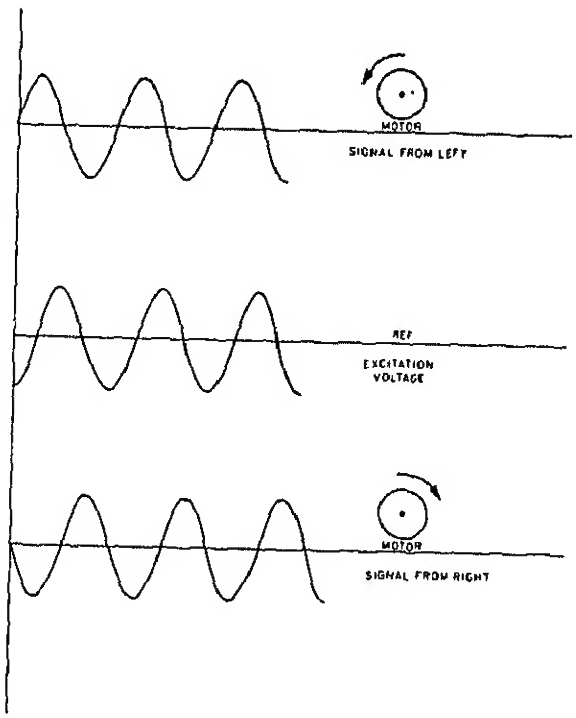


Figure 6 Saturation Transformer

8. Phase Detector, Q8, Q9, Q10, & T2



Saturation Transformer Signal

Figure 7

9. Rate Generator

10. Synchro Transformer

INFORMATION SHEET 4.11.1I

BASIC FM THEORY

INTRODUCTION

For better understanding of the material covered in this lesson, this information sheet will provide you with the definitions necessary for the study of basic FM theory.

REFERENCES

1. Electronics Circuit Analysis, Vol. II, NAVAIR 00-80-T-79, pages 9-3 to 9-4, 9-17 to 9-24.

2. Electronic Communication, Shrader McGraw-Hill, Fourth Edition, pages 452-482, 1980.

3. Electronic Circuits, NAVSHIPS 0967-LP-000-0120, pages 12-89 to 12-95.

INFORMATION

1. Freqeuncy modulation - varying the frequency of the RF energy at an audio rate in order to convey intelligence.

2. Modulation index - the maximum frequency deviation, divided by the frequency of the audio signal voltage.

3. Deviation ratio - the ratio of the greatest allowable deviation to the highest modulating frequency.

   Note: Modulation index is equal to the deviation ratio when the maximum deviation allowable (75 kHz) is used with the highest modulating frequency allowable (15 kHz).

4. Demodulation - the removal of the audio from the RF carrier. Usually used in FM as the word detection is used in AM.

5. Rest frequency - the unmodulated radio frequency. Also called the center frequency in FM.

NOTETAKING SHEET 4.11.1N

BASIC FM THEORY

REFERENCES:

1. Electronic Circuit Analysis, Vol. II, NAVAIR 00-80-T-79, pages 9-3 to 9-4, 9-17 to 9-24

2. Electronic Communication, Shrader McGraw-Hill, Fourth Edition, pages 452-482, 1980.

3. Electronic Circuits, NAVSHIPS 0967-LP-000-0120, pages 12-89 to 12-95.

NOTETAKING OUTLINE:

A. Terms and Definitions

B. Basic Frequency Modulation

    1. Frequency Modulation

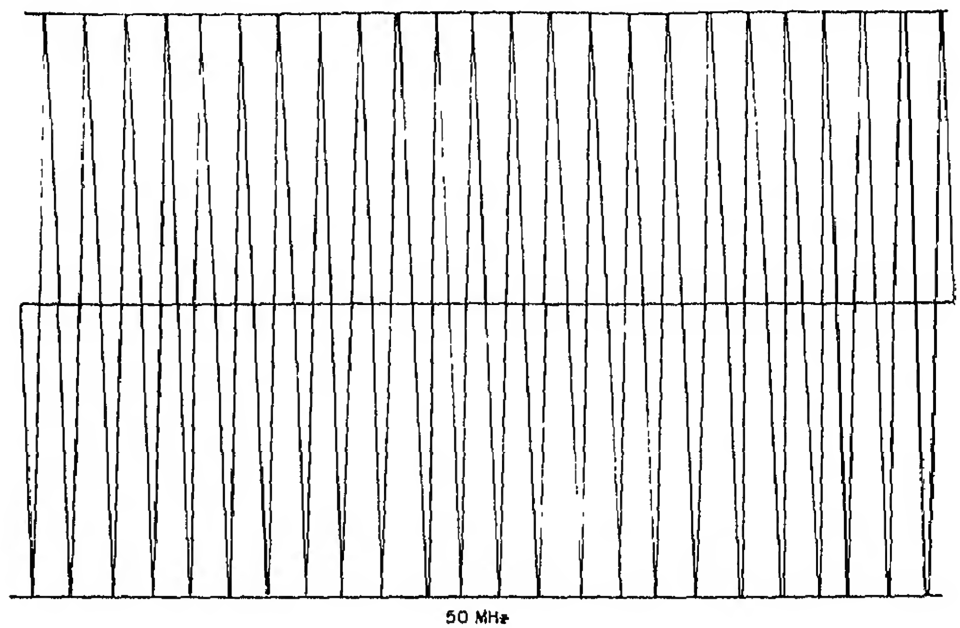


Figure 1 unmodulated RF.

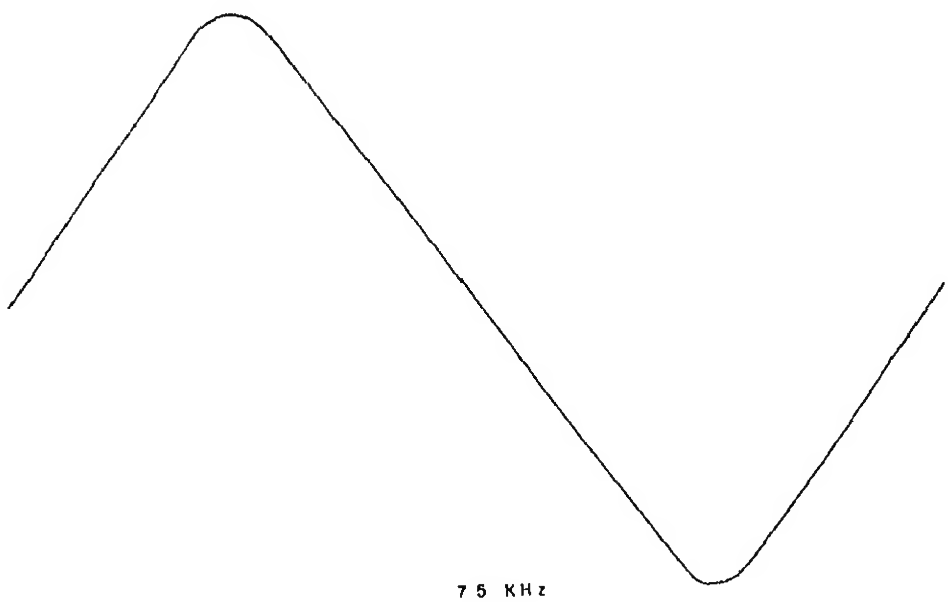


Figure 2 Audio signal.

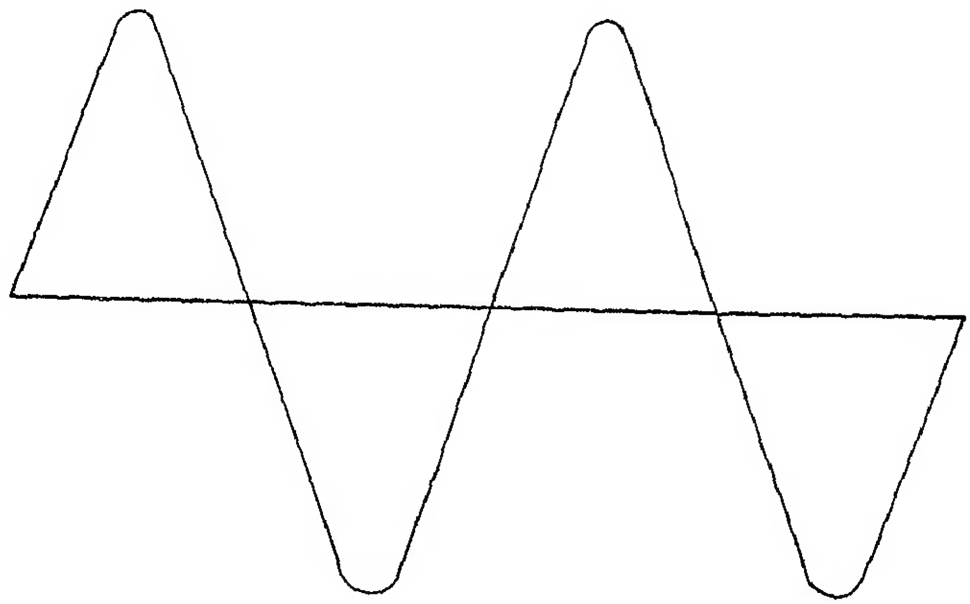


Figure 3 Audio signal.

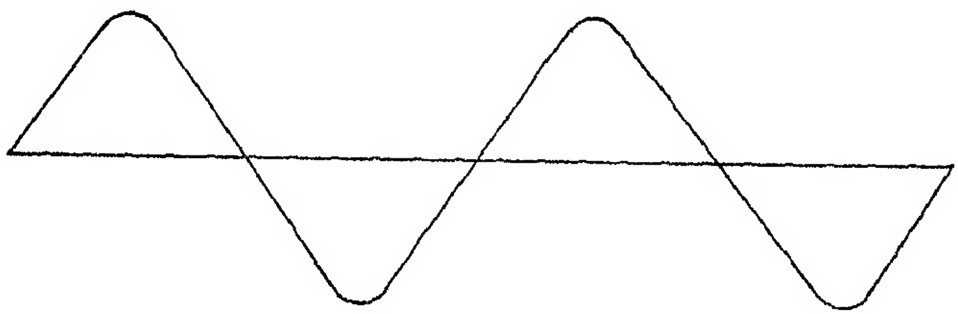


Figure 4 Low power audio signal.

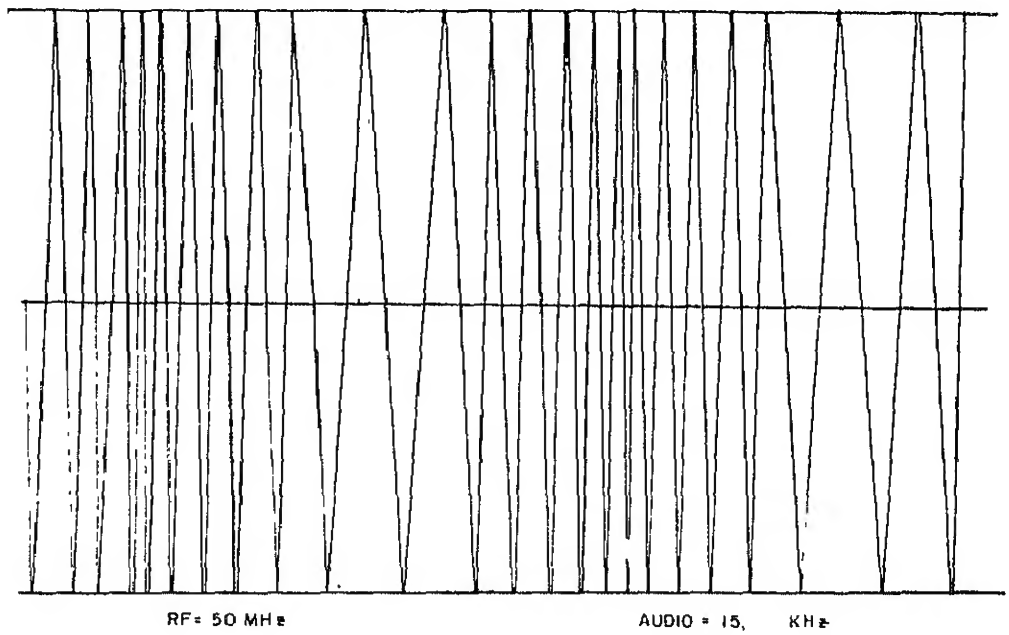


Figure 5 50% modulated signal,

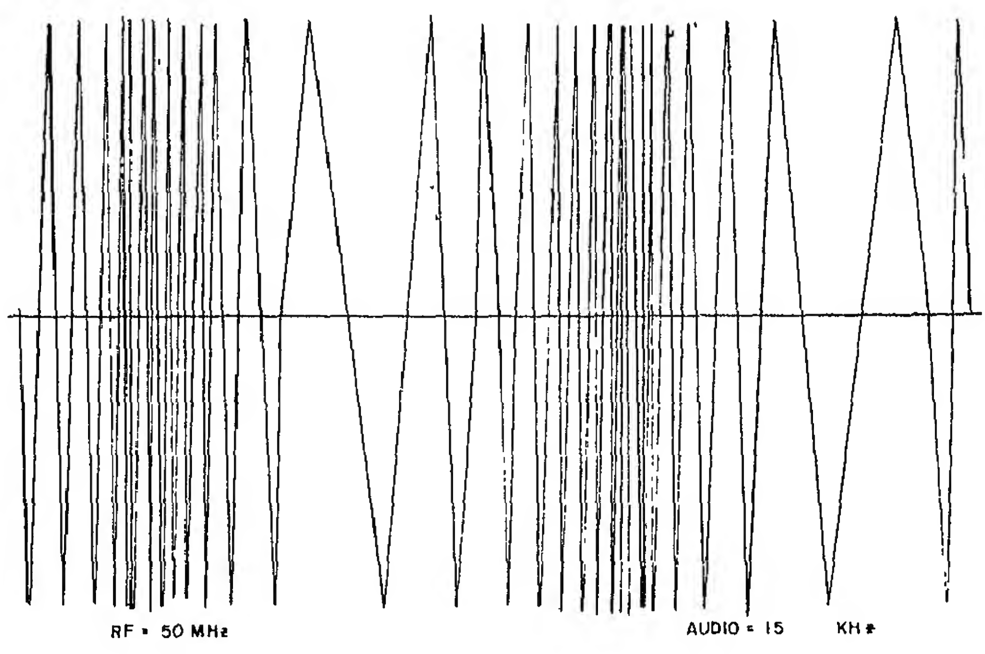


Figure 6 100% modulated signal.

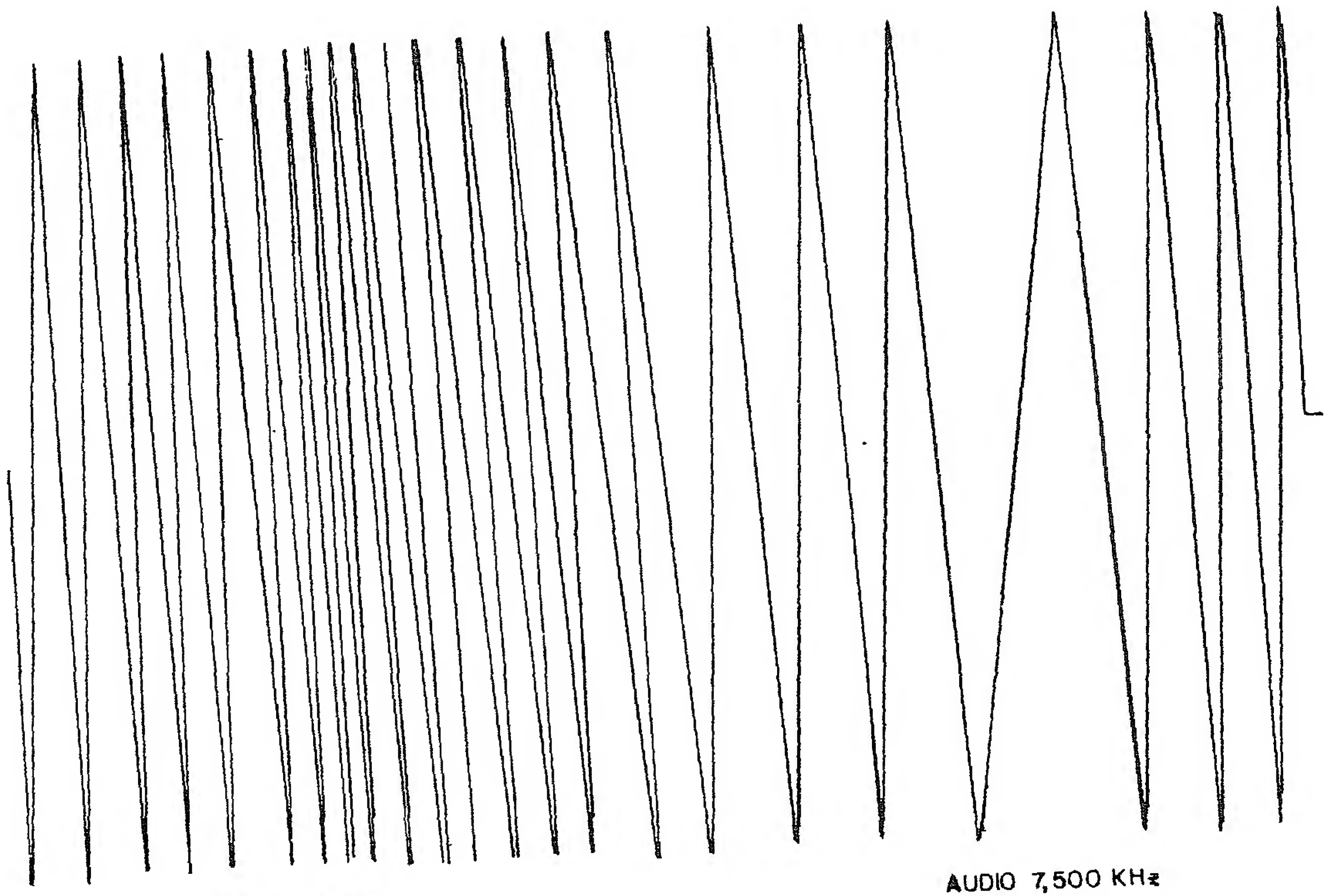


Figure 7 - Modulated by a lower frequency.

3. Bandwidth

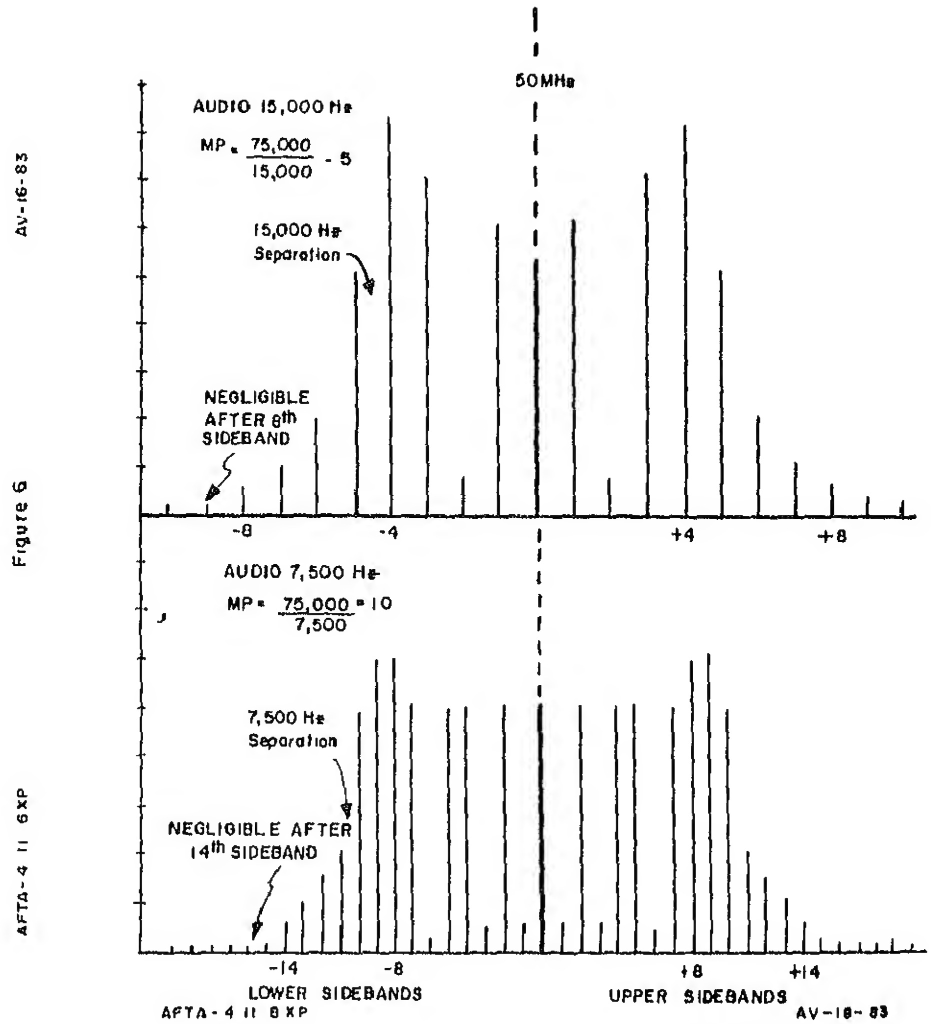


Figure 8 FM spectrum.

MODULATION INDEX $M = \frac{fd}{fa}$	NUMBER OF EFFECTIVE SIDEBAND PAIRS	EFFECTIVE BANDWIDTH (SEE NOTE BELOW)
.5	2	4FA
1	3	6FA
2	4	8FA
3	6	12FA
4	7	14FA
5	8	16FA
6	9	18FA
7	11	22FA
8	12	24FA
9	13	26FA
10	14	28FA
11	16	32FA
12	17	34FA

NOTE: To calculate effective bandwidth (BW) in kilohertz, multiply the number of effective sidebands by the audio modulating frequency. For example, if M = 2 and fa = 5KHz, then BW = 8fa or BW (KHz) = 8x5KHz = 40KHz.

Figure 9 FM table.

4. Modulation Index (M)

5. Power

6. Advantages of FM

C. FM Circuits

1. Modulator

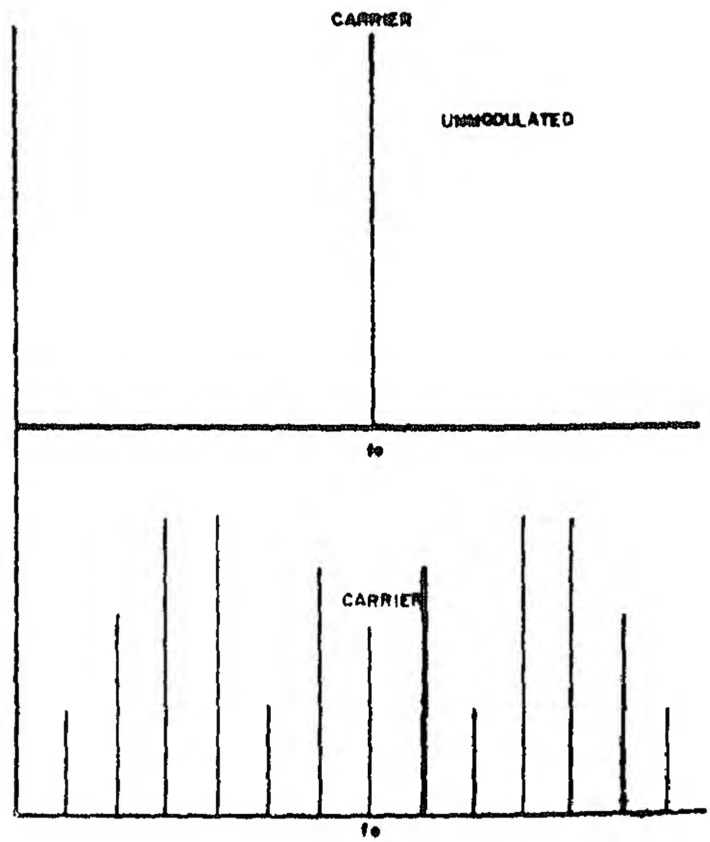


Figure 10 Power distribution.

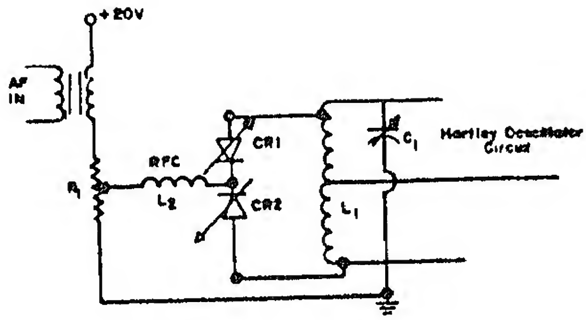


Figure 11 Varicap modulator.

2. Discriminator

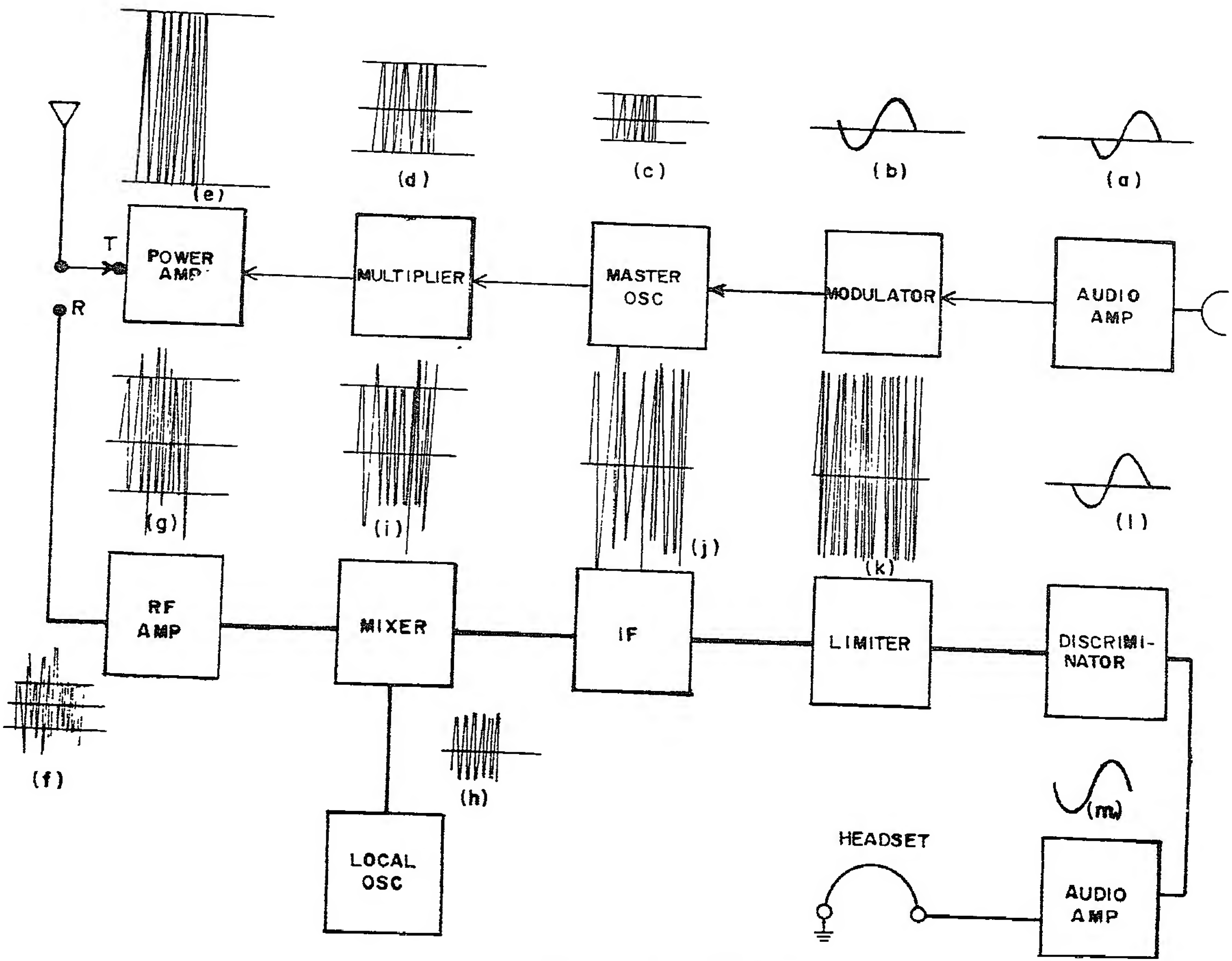


Figure 12 Block diagram.

D. A Typical Basic FM Transceiver

1. Transmitter

2. Receiver

FILM GUIDE 4.12.1F

SINGLE-SIDEBAND RADIO INTRODUCTION

INTRODUCTION

The purpose of this Film Guide is to provide you with guidance on what to look for in film 87726DN, "Single-Sideband Radio Introduction." In addition, this guide will be used in place of a notetaking sheet for the material covered in the film. It also includes an in-class assignment to ensure understanding of the material. The film will provide you with an understanding of standard amplitude modulation techniques, will point out the advantages of single-sideband communications over conventional AM, and how single-sideband is used to conserve the available frequency spectrum. Upon completion of the film, the material will be reviewed.

Points to look for

1. Generation of conventional amplitude modulation

    a. Sideband operation.

    b. Which elements of a conventional AM contain intelligence.

2. Generation of a single sideband

    a. Balanced modulator.

    b. Sideband filter.

3. Advantage of single-sideband over conventional AM

    a. Frequency spectrum conservation.

    b. Power utilization.

    c. Radio interference (signal-to-noise ratio).

    d. Selective fading.

4. Limitations of single-sideband

    a. Linear amplification.

    b. Need for more complex circuits.

    c. Precise frequency control.

Show Film--87726DN "Single-Sideband Radio Introduction"

Review Questions

1. Why is the theoretical signal-to-noise ratio better in SSB?

____a. Atmospheric noise is less at SSB frequencies.
____b. Narrower bandwidth.
____c. There is no noise generated by the carrier.
____d. More RF amplifiers are used.

2. Why did the jeep motor loaf between words in the transmission?

____

3. What is the major advantage of SSB? ____________________

INFORMATION SHEET 4.12.1I

SINGLE-SIDEBAND PRINCIPLES

INTRODUCTION

To facilitate the study of single-sideband theory, it it necessary to understand a few basic concepts, terms, and definitions. This information sheet is provided for your understanding.

REFERENCES

1. Electronic Circuit Analysis, Vol. II, NAVAIR 000-80-T-79, Pages 9-24 to 9-44.

2. HSI, NAVAIR 16-30ARC-94-1, Section IV.

INFORMATION

1. Definition- Single-sideband is a method of transmission, whereby the RF carrier and one sideband of a double-sideband amplitude-modulated signal are suppressed and only one sideband is utilized. (There are several types of single-sidebands and each encompasses, to some degree, the suppression of one side-band, and or the carrier, then utilizing one sideband dependent upon the need).

2. Single-sideband types are known as follows; suppressed carrier, compatible single-sideband, pilot or exalted carrier, and vestigial carrier.

3. The suppressed carrier is generally implied when anyone says single-sideband and it means that the carrier and one sideband is suppressed approximately 30-50dB (1000-100,000 times) below the transmitted peak power. Also, the receiver must reinsert the carrier for demodulation in suppressed carrier.

4. The compatible single-sideband indicates that the carrier and one sideband is transmitted for conventional AM receivers to allow a transition period from AM to SSB, which is used in the military.

5. The pilot carrier is where one sideband and the carrier is suppressed and the carrier is reinserted approximately 10-20dB below the peak power to be used to tune the receiver, as well as being used in an amplified form to demodulate.

6. The vestigial sideband is where the carrier and one sideband are partially suppressed, as in television transmission.

7. The advantages of SSB are in spectrum conservation, power utilization, selective fadings, and single-to-noise ratio.

8. Spectrum conservation is happening because less than one-half of the RF is used and two pieces of equipment can be used using the opposite sideband, creating a more efficient use of the RF energy.

9. The power utilization is due to the fact that full power is only used from the power source during modulation and the SSB transmitted power contains 100% intelligence. Translated, that means that a 50 watt SSB transmitter can replace a 400 watt dual-sideband transmitter. (1/8 of a DSB or approximately 9dB less).

10. Selective fading is reduced because there is only one sideband bringing intelligence in.

11. The signal-to-noise is greatly improved because of the reduction of the bandwidth requirements.

HF OSCILLATOR OPERATING FREQUENCIES

(MHz)

OPERATING FREQ (MHz)	HF OSC FREQ (MHz)	OPERATING FREQ (MHz	HF OSC FREQ (MHz)
2-2.999	12.5*	14-14.999	8.5**
3-3.999	11.5*	15-15.999	9.0**
4-4.999	10.5*	16-16.999	9.5**
5-5.999	9.5*	17-17.999	10.0**
6-6.999	8.5*	18-18.999	10.5**
7-7.999	10.0	19-19.999	11.0**
8-8.999	11.0	20-20.999	11.5**
9-9.999	12.0	21-21.999	12.0**
10-10.999	13.0	22-22.999	12.5**
11-11.999	14.0	23-23.999	13.0**
12-12.999	15.0	24-24.999	13.5**
13-13.999	16.0	25-25.999	14.0**
		26-26.999	14.5**
		27-27.999	15.0**
		28-28.999	15.5**
		29-29.999	16.0**

*These HF Oscillator frequencies are mixed with the 14.5 to 15.5 MHz output from the 17.5 Mixer.

**These HF Oscillator frequencies are doubled before injection into the HF Mixer.

Note: The RF Oscillator is capable of putting out 16 different frequencies.

NOTETAKING SHEET 4.12.1N

SINGLE-SIDEBAND PRINCIPLES

REFERENCES:

1. Electronic Circuit Analysis Vol. II, NAVAIR 000-80-T-79, pages 9-24 to 9-44.

2. HSI, NAVAIR 16-30ARC-94-1, Section IV.

NOTETAKING OUTLINE:

A. Concepts of Single-Sideband

   1. General Information

   2. Single-Sideband types

3. Advantages

4. Disadvantages

5. Special Circuit Requirements (suppressing the carrier)

6. Sideband Selection

7. Compatibility of SSB and DSB

B. Basic Single-Sideband Transmitter

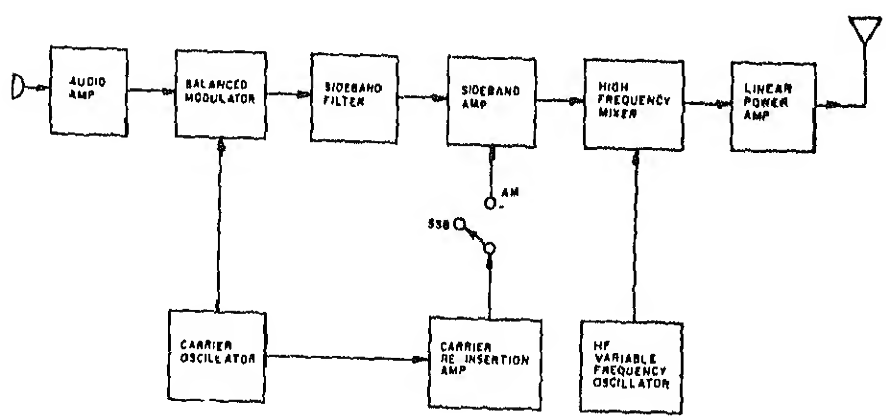


Figure 1 Basic single-sideband transmitter block diagram

C. Basic Single-Sideband Receiver

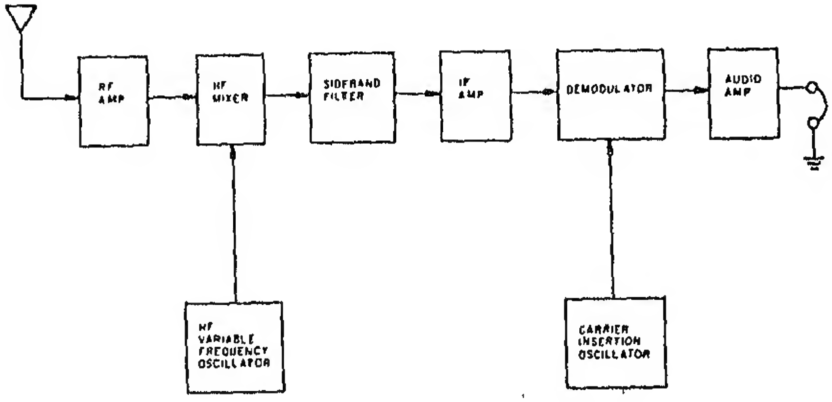


Figure 2 Basic single-sideband receiver block diagram.

D. Typical Single-Sideband Transceiver

1. General Information

2. Transmitter

3. Receiver

4. Frequency Synthesis

NOTETAKING SHEET 4.13.1N

SINGLE-SIDEBAND SPECIAL CIRCUITS

REFERENCES:

1. Electronic Circuits Analysis, Vol. II, NAVAIR 000-80-T-79, pages 9-24 to 9-44.

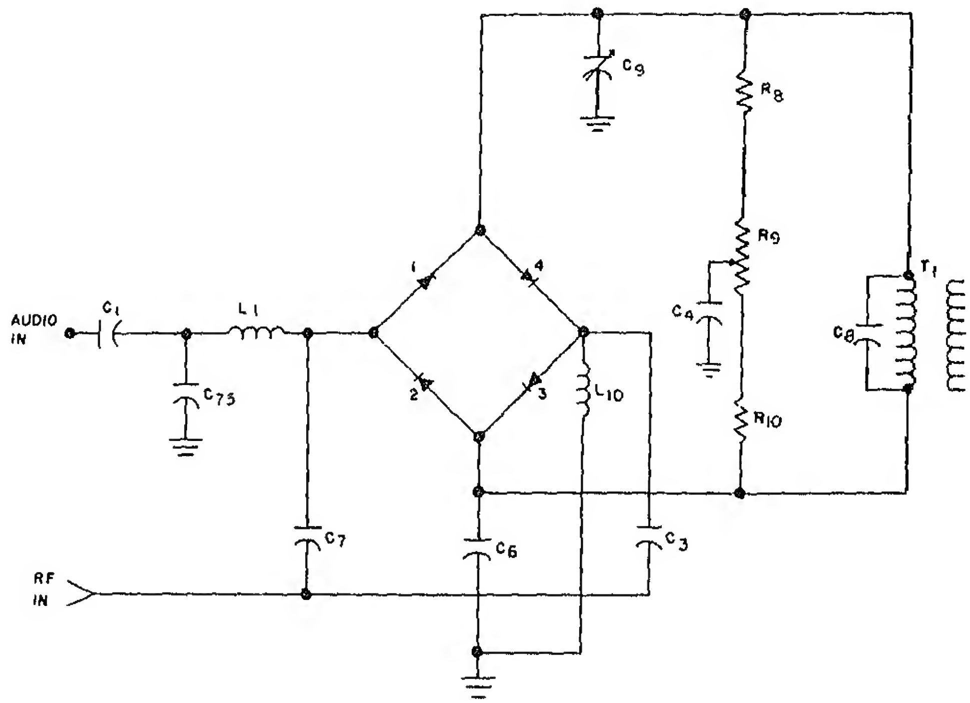
2. Handbook of Service Instructions, NAVAIR 16-30, ARC-94-1, Section IV.

NOTETAKING OUTLINE:

A. Balanced Modulator

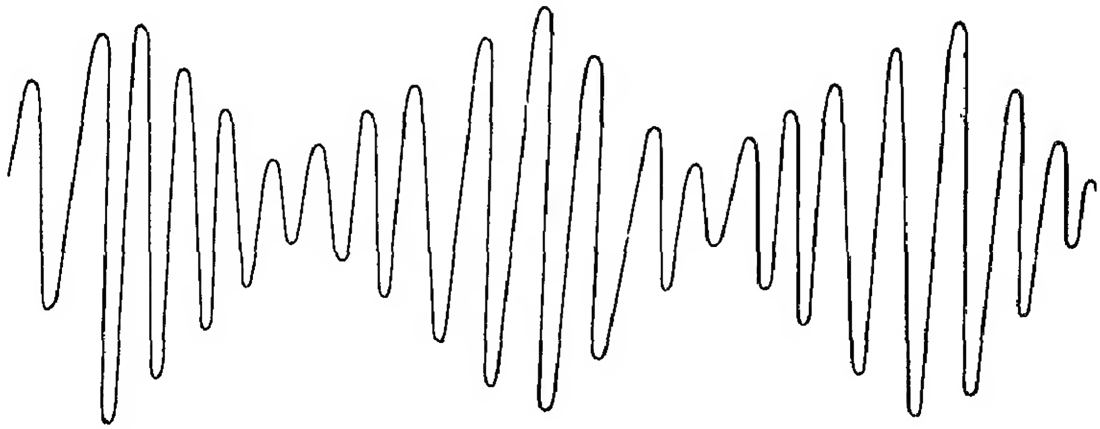
    1. Purpose

    2. Circuit Analysis



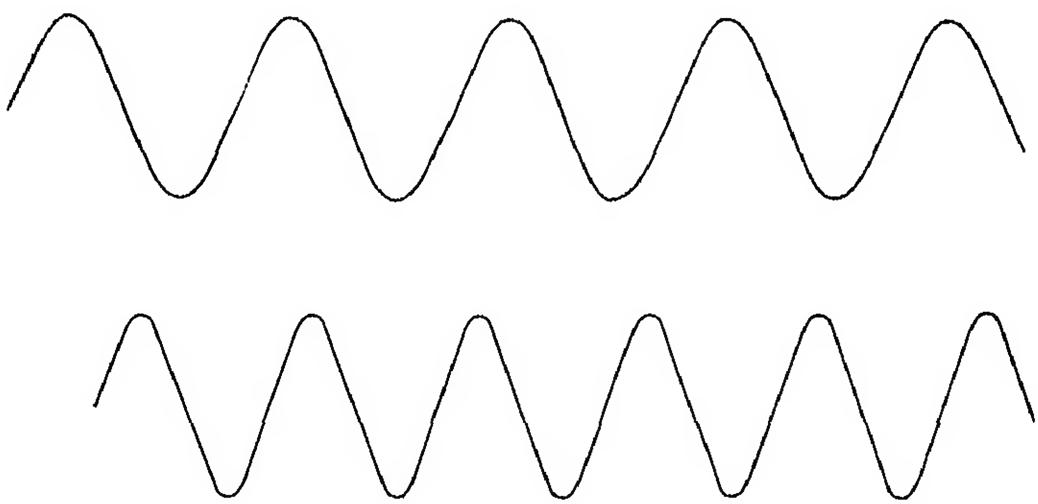
Balanced Modulator

Figure 1



Voltage Diagram of Two Signals

Figure 2



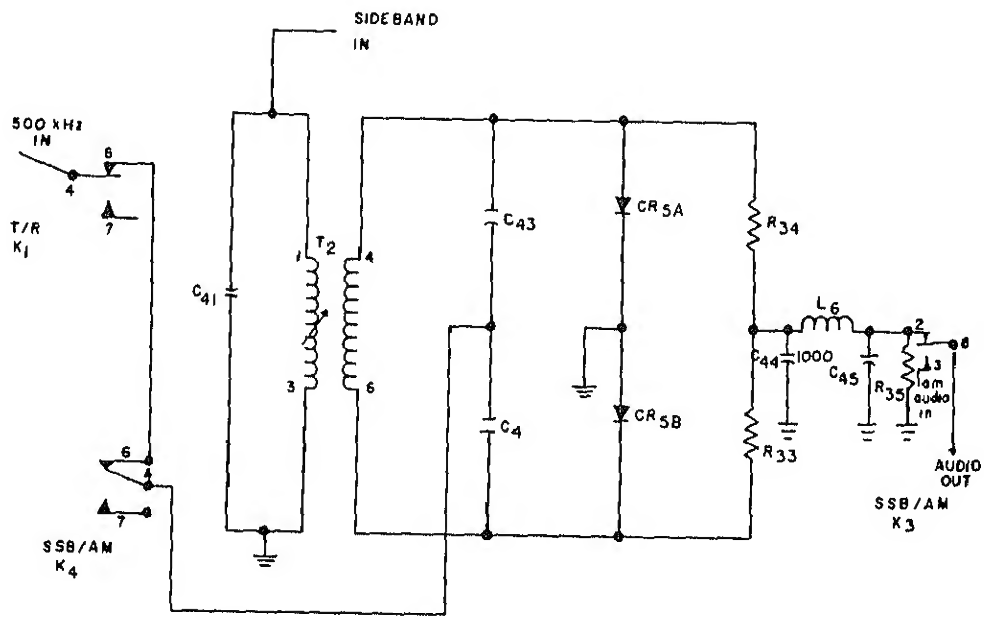
Upper and Lower Sidebands

Figure 3

B. Product Detector

1. Purpose

2. Circuit Analysis



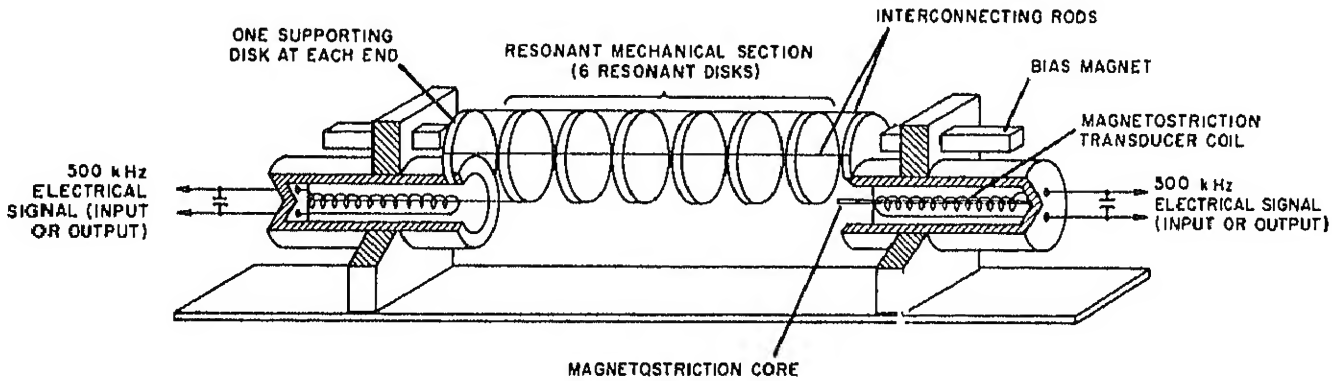
Product Detector

Figure 4

C. Mechanical Filters

1. Purpose

2. Bandpass



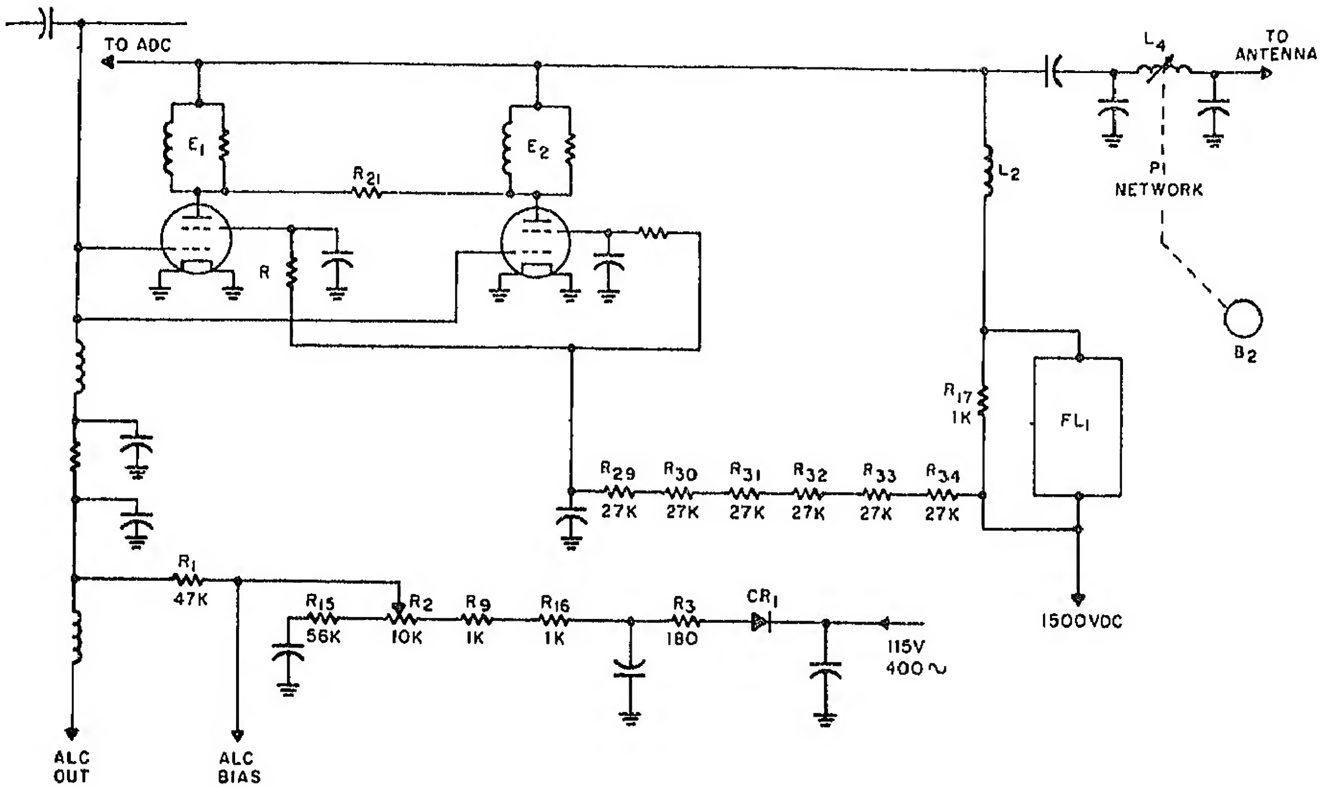
Mechanical Filters

Figure 5

3. Operation

D. Linear Power Amplifiers

1. General information



Linear Power Amps

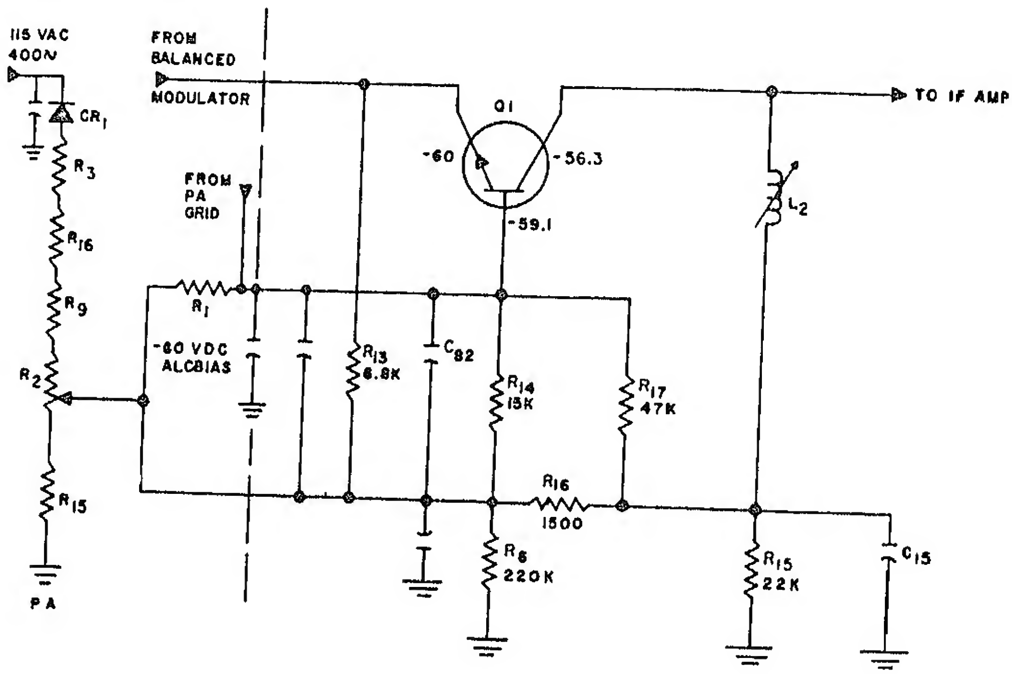
FIGURE 6

E. Automatic Load Control Amplifier

1. General information

2. Supply voltages

3. Signal flow



ALC Amplifier

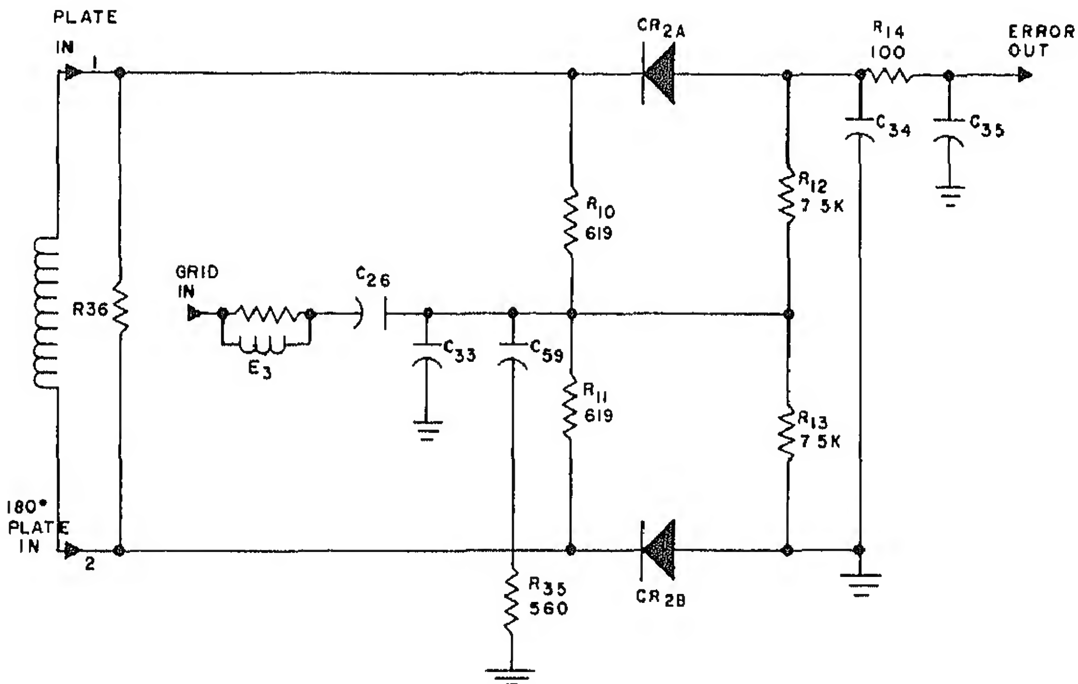
FIGURE 7

2. Supply voltages

3. Signal flow

F. Phase Discriminator and Electronic Control Amplifier

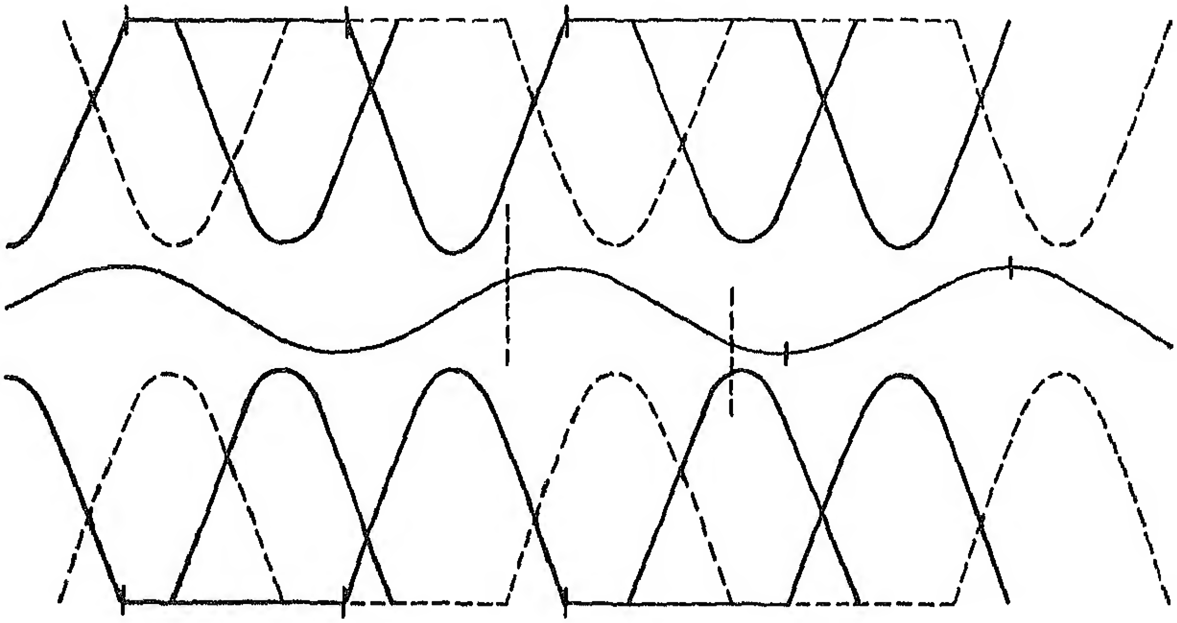
1. General Information



Phase Discriminator

FIGURE 8

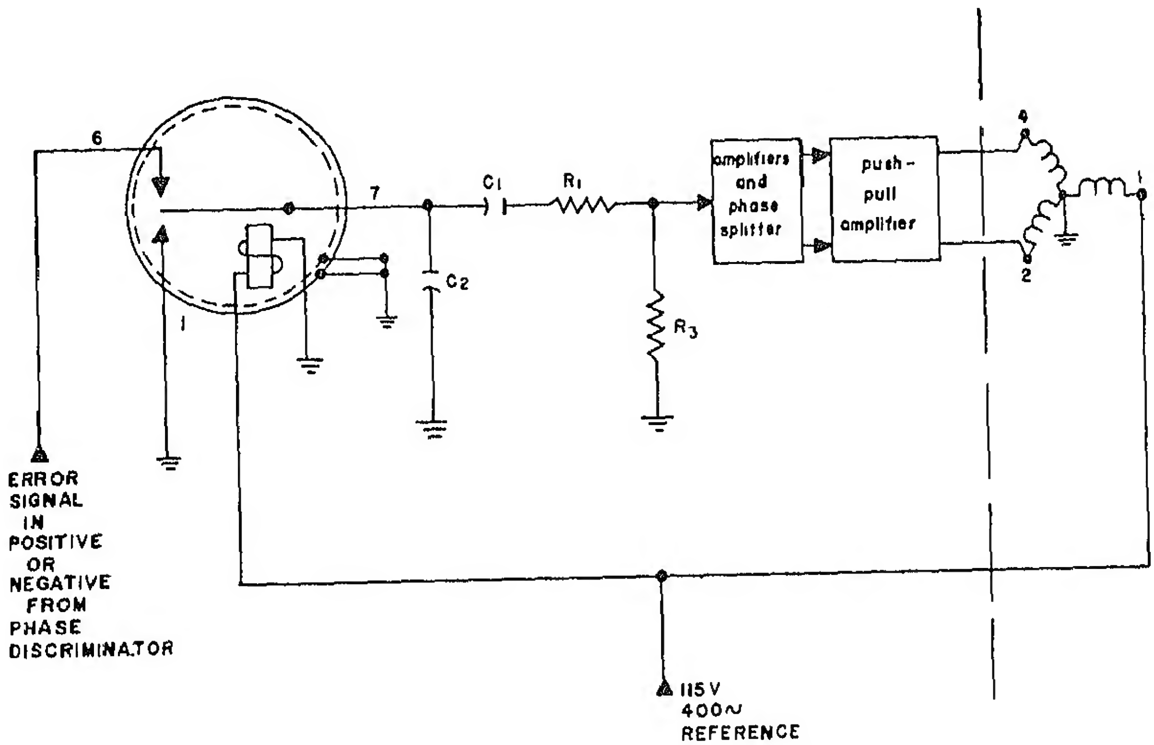
2. Phase Discriminator



Error and Reference Signals

Figure 9

3. Electronic-Control Amplfier



Motor Control

Figure 10

FILM GUIDE 4.14.1F

OPTIMIZATION OF HIGH FREQUENCY COMMUNICATION

INTRODUCTION

The purpose of this Film Guide is to provide you with guidance on what to look for in film 25686DN, "Optimization of High Frequency Communication." In addition, this guide is to be used in place of a notetaking sheet for the material covered in the film. It also includes an in-class assignment to ensure understanding of the material. The film will show that the sky wave is the only practical method for long-range communication. Upon completion of the film, the material will be reviewed.

Points to look for

1. Methods of propagation

    a. Direct waves

        (1) Line of sight.

        (2) Not usable for long-range communications.

        (3) Limited range due to antenna height.

    b. Ground waves

        (1) Losses caused by earth.

        (2) Requires too much power for long-range communication.

    c. Sky waves

        (1) Causes of ionosphere.

        (2) Effect of angle of radiation on refraction.

        (3) Effect of frequency on refraction.

        (4) Variations of ionosphere.

2. Radiation and receiving with antennas

3. Measurement of ionosphere conditions and tables for calculations of optimum communications.

Show Film--25686DN "Optimization of High Frequency Communication."

Review questions

1. What changes take place in the ionosphere at night?

____a. D and E layers disappear, while F1 and F2 combine.
____b. F1 and F2 layers disappear, while D and E layers combine.
____c. Ionosphere completely disappears.
____d. All layers shift to a higher level.

2. The refraction of radio waves is

____a. the bending of radio waves around solid objects.
____b. the reradiation of radio waves by the ionosphere.
____c. the bending of radio waves when passing into a medium of different density.
____d. the attenuation of radio waves when passing into a medium of different density.

3. What are the three factors that effect the refraction of radio waves by the ionosphere?

____a. Antenna location, density of the ionosphere, frequency.
____b. Angle of radiation, antenna height, frequency.
____c. Angle of radiation, density of the ionosphere, frequency.
____d. Atmospheric noise, frequency, antenna height.

4. As night approaches, what must be done to frequency to maintain optimum communications?

____a. Increase.
____b. Decrease.

INFORMATION SHEET 4.14.1I

RADIO WAVE PROPAGATION

INTRODUCTION

Radio wave propagation is the travel of electromagnetic waves through a medium and is defined as the transfer of energy by electromagnetic radiation at frequencies below 3 terahertz. To enhance your learning, this information sheet will provide you with detailed information on ground waves, sky waves, and anomalous propagation.

REFERENCES

1. Electronic and Radio Engineering, Terman, McGraw-Hill, 4th Edition, Chapter 22.

INFORMATION

A. GROUND WAVES

1. GENERAL: A ground wave, figure 1, consists of three components: (1) a direct wave; (2) an earth-reflected wave, and (3) a surface wave. The direct wave travels approximately in a straight-line path from the transmitting antenna to the receiving antenna. The earth-reflected wave travels from the transmitting antenna to earth, from which it is reflected to the receiving antenna. The surface wave travels directly along the surface of the earth from the transmitting antenna to the receiving antenna.

2. DIRECT WAVE: The direct wave, figure 1, is used for straight-line communication between ground (or ship) installations and aircraft, or between two aircraft. However, for communication between two points on the surface of the earth, both the transmitting and receiving antennas must be elevated to obtain a clear path. Large buildings, hills, mountains and even the curvature of the earth (over long distances) become major obstacles. Even when a clear path can be obtained, the direct wave is not usable at some specific distance for frequencies below about 30 MHz. At these frequencies, it is often impractical to build an antenna large enough to have good directivity, hence the radiated energy has a very broad angle coverage. As a result, some of the radiated energy strikes the earth's surface and is then reflected to the receiving antenna.

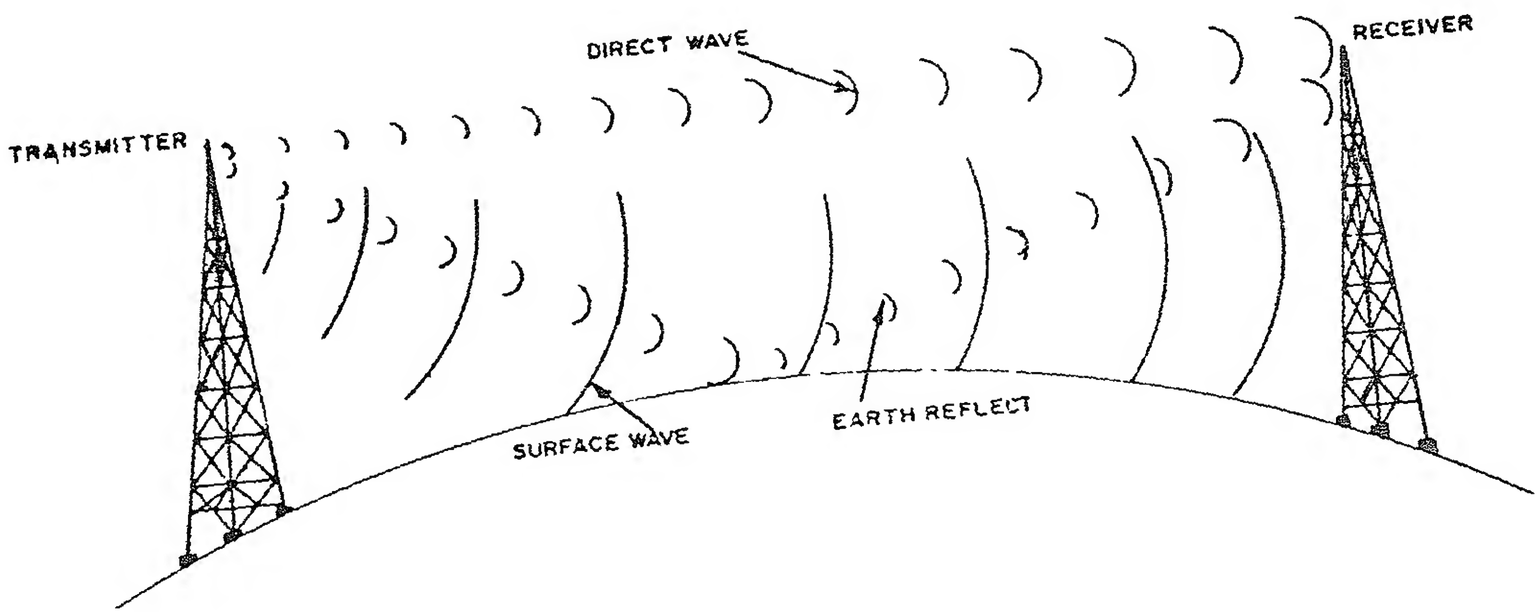


Figure 1 COMPONENTS OF GROUND WAVE

3. EARTH-REFLECTED WAVE: The energy reflected by the earth (earth-reflected wave) may not arrive at the receiving antenna in phase with the direct-wave energy because of the difference in path lengths and the phase reversal that may occur when radio waves are reflected.

If the two signals arrive at the receiving antenna 180° out of phase, the earth-reflected wave may completely cancel the direct wave. At frequencies below 20 MHz, direct-wave cancellation may be almost complete, and the signal reaching the receiver may be very weak. At the higher frequencies (VHF) (UHF) and (SHF), the transmitting antenna can be made to focus the radiated energy into a narrow beam that travels directly to the receiving antenna with little or no earth reflection. The higher frequencies are generally used for short-range communication because the earth-reflected wave can be avoided or made negligible.

If the beam of a transmitting antenna is focused so that most of the energy travels along the horizon, and if both the transmitting antenna and the receiving antenna are elevated high above the surface of the earth, radio waves will travel directly from one antenna to the other with little or no interference due to reflections. The communication distance, in this case, is limited only by the curvature of the earth. This distance is somewhat longer than might be expected. Instead of going straight out into space, the energy radiated from the transmitter antenna tends to follow the curvature of the earth. This happens because the dielectric constant of the atmosphere through which the radio waves travel is not uniform throughout. The dielectric constant of the atmosphere usually decrease with increased height above the earth. Remember from earlier discussions, the lower the dielectric constant, the greater the velocity of propagation of the electromagnetic waves. With the dielectric constant largest near the earth's surface, the electromagnetic wave is bent toward the earth's surface.

Figure 2 shows the straight-line path that ray "A" would take if it were moving through an atmosphere with a uniform dielectric constant. Note that, beyond the optical horizon, ray "A" is moving away from the surface of the earth into space. In this region, a receiving antenna would have to be elevated a considerable distance above the earth to intercept the transmitted beam. The curved ray "B", figure 2, represents the actual path of a ray in an atmosphere that decreases in dielectric constant as altitude increases. The point at which ray "B" touches the earth is called the radio horizon. The radio horizon is farther from the transmitting antenna than the optical horizon. the ending of rays is much more pronounced at lower frequencies than at the higher frequencies. Thus, VHF rays (30 to 300 MHz) are bent more than the UHF rays (300 to 3000 MHz).

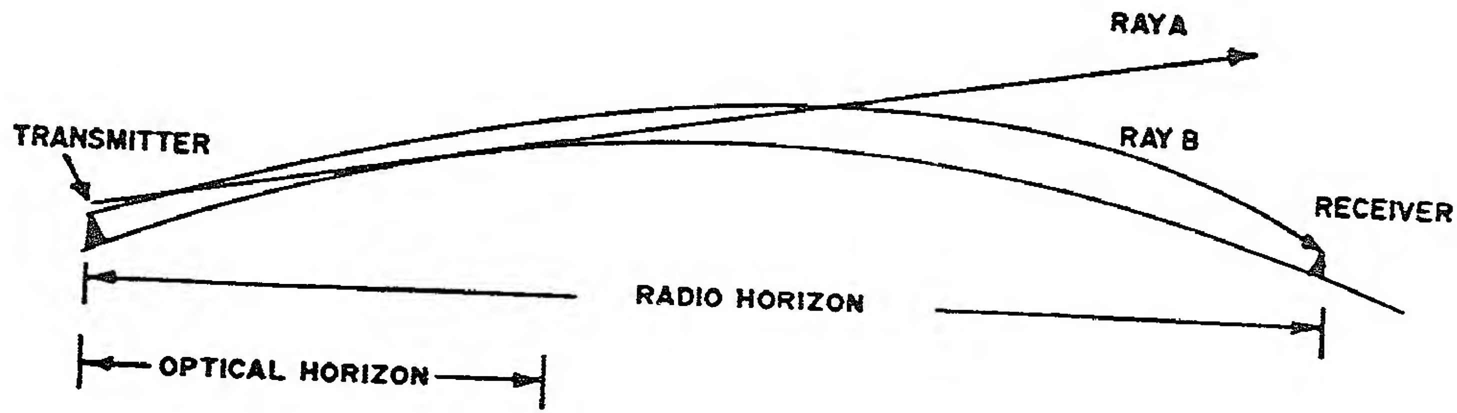


Figure 2 EFFECT OF ATMOSPHERE ON GROUND WAVE

4. SURFACE WAVE: When both the transmitting and receiving antennas are close to the earth's surface, the direct wave and the earth-reflected wave may cancel each other. This would leave only the surface wave, which travels in contact with the earth's surface. To be propagated along the earth's surface, a surface wave must be vertically polarized (the E-field perpendicular to the earth). If the E-field is parallel to the earth, very little energy is propagated by the surface wave.

B. SKY WAVE PROPAGATION

1. THE IONOSPHERE: When radio was young, most scientists assumed that long-distance communication by the new medium would not be possible. For, after all, even if the radio wave were to be diffracted around the bulge of the earth, it would soon die out because of absorption. Then in 1901, Marconi was able to transmit and receive a signal across the Atlantic Ocean, causing the scientists to reconsider. In 1902, Sir Oliver Heaviside in England wrote, "There may possibly be a sufficiently conducting layer in the upper air." In that same year, Professor Arthur Kennelly of Harvard University reported, "On waves that are transmitted to distances that are large, it seems likely that the waves may also find an upper reflecting surface in the conducting rarefied strata of air." By 1925, scientists were sending pulses of radio energy upward into space and then finding that echoes of those pulses could be received a short time later. These and many other experiments confirmed the now accepted fact that a region of ionized gases exists in our upper atmosphere which can act on radio waves. This region was named the ionosphere. The ionosphere consists of several more or less well defined layers which act to reflect radio waves.

The earth's atmosphere is subjected to a constant state of bombardment by radiation and particle showers from the sun and by cosmic rays from unknown sources. The radiation from the sun includes not only visible light energy but also infrared and ultraviolet radiation. In addition, showers of fast-moving electrons and positrons constantly pour onto our atmosphere.

As these different forms of radiation approach the earth, they reach certain critical levels where the density and types of the gases in our atmosphere are particularly susceptible to ionization by their action. As a result, ionization layers are formed. The uppermost portion of our atmosphere seems to be affected mostly by particle radiation, although most of the ionization is probably due to the sun's ultraviolet radiation.

Conditions in our upper atmosphere are highly favorable for ionization. This is true, since the upper atmosphere is directly exposed to the sun and, because of its low density, once ionization occurs, the particles remain ionized for relatively long periods. The rate of ionization of the gases in our upper atmosphere is about 100 times greater than the normal ionization of gases at the earth's surface.

Because the source of ionization is the sun, it is natural to expect that unusual disturbances on the sun should have a widespread effect on radio communication. Tremendous clouds of hot gases occasionally erupt from the face of the sun to distances of a half-million miles. These bright visible flares which burst from the sun's surface produce great and sudden increases in the ion density which extends down to the lower levels of the ionosphere. This results in an effect called the "Dellinger fade," which will be discussed shortly. Also, during periods of high sunspot activity, the amount of ionization of the various layers in the ionosphere is greater than normal. The processes involved in producing sunspots, which are sometimes seen as dark areas on the sun, produce great amounts of ultraviolet energy.

Sunspots usually appear in groups and follow a rather definite cycle of activity. There is an average time interval of 11.1 years between the maxima of two consecutive cycles. Magnetic storms on the earth are also related to the presence of large sunspots.

2. IONOSPHERE LAYERS: There are four distinct layers of the ionosphere. These are called, in order of increasing heights and intensities, the D, E, F_1, and F_2 layers. The relative distribution of these layers around the earth is shown in figure 3, "Ionospheric Layers Around the Earth." In order to show these layers, their heights compared to the size of the earth have been considerably exaggerated. During the night, when the sun's radiation no longer strikes the atmosphere, the two lower layers dissipate and the two upper layers combine into a single F layer as shown. It is important to realize that the actual number of layers, their heights, and the intensity of ionization, all vary from hour to hour, from day to day, from month to month, from season to season, and from year to year. Although this tends to make sky wave propagation somewhat less reliable than ground wave propagation, if most of the variable factors are understood and taken into account, some remarkable and dependable communication results are possible.

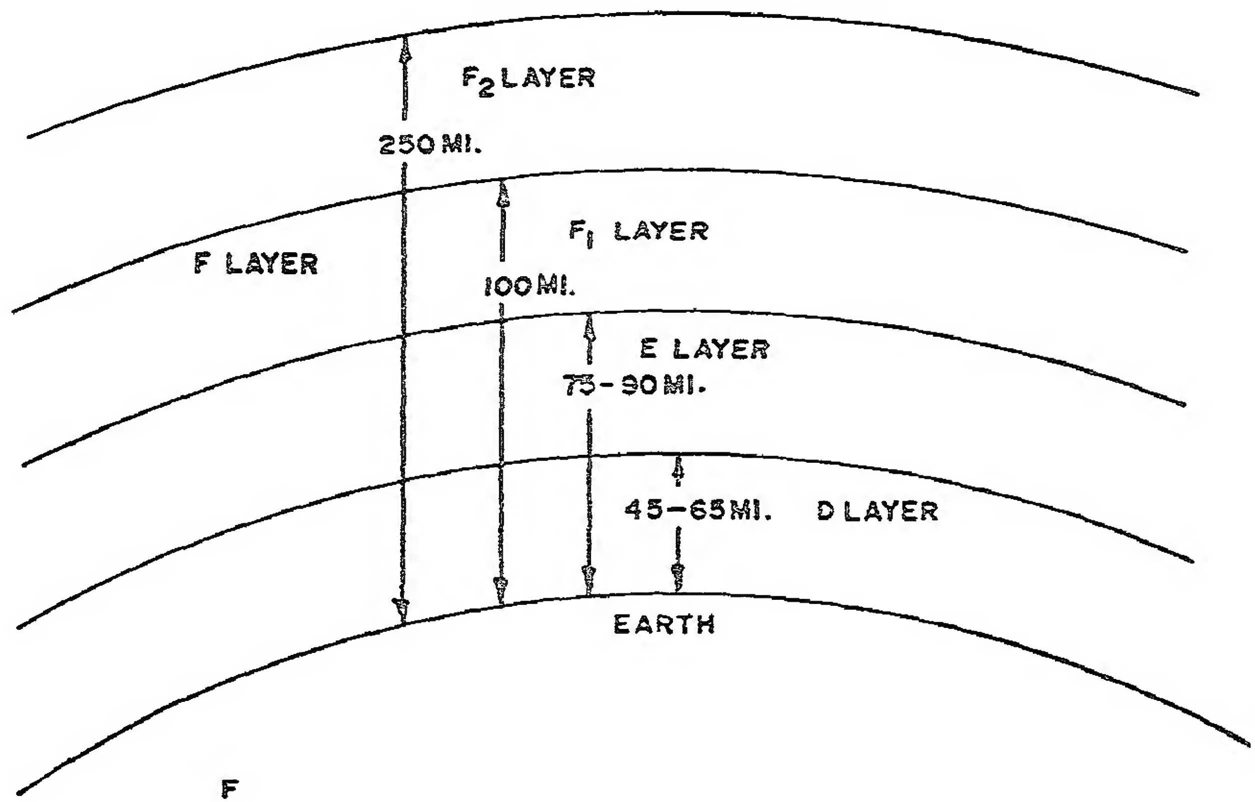


Figure 3 IONOSPHERIC LAYERS AROUND THE EARTH

The D layer is the lowest region of pronounced ionization. It extends from about 45 to 65 miles above the surface of the earth. The amount of ionization in this region is not extensive compared to the amount in other layers; hence, little bending of the paths of radio signals occur. The main effect of the ionization in the D layer is to weaken or attenuate the field intensity of high-frequency radio waves which cross through this region and to cause complete absorption of low and medium-frequency radio waves. This layer exists only during the daylight hours and its intensity is greater at noon when the sun is highest in the sky. Shortly after sunset, the D layer disappears. This layer causes the intensity of high-frequency waves to be reduced when the transmission occurs during daylight hours.

The E layer, sometimes called the Kennelly-Heaviside region, lies between 75 and 90 miles. The height of this layer varies somewhat with the seasons. The density of ionization follows the sun's altitude variations closely, reaching a maximum at noon. During the night, the E layer weakens so that it is useless for high-frequency radio communication. The number of free electrons liberated by the ionization process is high enough during the day to send radio waves whose frequencies are as high as 20 MHz back to earth. This layer is important for distances less than about 1500 miles. For longer distances, the radio wave would have to enter the ionosphere at a very small vertical angle with respect to the earth so that considerable absorption would occur in the ionosphere. Thus, long-distance transmission by means of the E layer is poor. Better long-distance transmission can be accomplished by the higher F_1 and F_2 layers.

At heights from about 100 to 250 miles above the earth's surface is the highly ionized F layer. During the daylight hours, especially when the sun is high, this region splits into two distinct layers: the F_1, whose lower limit is at a height of about 100 miles, and the F_2, whose lower limit is at a height of about 250 miles, depending on the season and time of day. These layers are the most useful for long-distance radio communication.

Other layers of ionized gases occasionally appear near the E layer. Sometimes the ionization is sufficient in these other layers to send radio waves back to the earth and enable good radio transmission to occur. Sometimes diffused ionization occurs over a large range of height. Under these conditions, no well-defined layers exist. As a result, long-distance radio transmisson is impossible because of the excessive absorption.

3. CHARACTERISTICS OF IONOSPHERE--Whenever radio energy enters the ionosphere, it may be reflected back to the earth. In measuring the height of an ionized layer, it is customary to "sound" the ionosphere. This is done by sending a pulse of radio-frequency energy upward and measuring the time required for the echo to return. As the velocity of propagation is known, the height of the layer can be calculated. Because the boundary of a layer is not well defined, the height thus calculated may be somewhat larger than the actual layer height.

In addition to height, the ionization density of a layer affects long-distance transmission. The higher the frequency, the greater the density of ionization needed to turn the waves back to earth.

Thus, the highly ionized upper layers can reflect the higher frequencies, while the least ionized D layer does not reflect frequencies much above 500 kHz.

There is a highest frequency above which a wave sent vertically upward is not returned to the earth. This frequency is called the "critical frequency." Each layer in the ionosphere has its own critical frequency, which varies depending on the time at which it is measured. Waves of all frequencies higher than the critical frequency will pass on through the ionized layer and will not be returned to earth unless from a still higher layer. Waves of all frequencies lower than the critical frequency are returned to earth unless they are absorbed by, or have been reflected from, a lower layer.

4. REGULAR IONOSPHERE VARIATIONS--The existence of the ionosphere depends largely on the radiations from the sun. Obviously, then, the movement of the earth about the sun or changes in the sun's state of radiation activity will produce variations in the ionosphere. Some of these variations are sufficiently regular to be predictable in advance. These are the so-called regular ionosphere variations. Then there are irregular variations caused by abnormal behavior of the sun. The regular variations can be divided into four classes. These are the daily or diurnal, the 27-day, the seasonal, and the 11-year.

The diurnal variations and their effects have been discussed earlier. Note that the tables suggest the use of higher medium frequencies during the day and lower medium frequencies at night. This is probably because of the greater ion density of the F_2 layer during the day which allows it to reflect higher frequencies than the F layer will reflect at night. When the higher-frequency waves pass through the D layer, they suffer less absorption.

C. ANOMALOUS PROPAGATION

1. The earth's atmosphere that extends from sea level up to a height of approximately 11 miles is named the TROPOSPHERE. This is the "weather layer" of our atmosphere. It is in this layer that our winds, storms, and rains exist that continually erode and alter the surface of the earth. The temperature of the troposphere decreases about 20° Fahrenheit for every mile of increasing altitude, reaching a minimum value of approximately -58° at the upper limit of the region. The meteorological changes in the troposphere are responsible for many of the VHF propagation conditions to be discussed.

2. ATMOSPHERIC REFRACTION--VHF signals that are transmitted along the surface of the earth do not travel in straight lines. Instead, they bend down slightly beyond the optical horizon because of absorption by the earth's surface of the lower portion of the wavefront. This causes the radio horizon to be extended as though the diameter of the earth were one-third larger than it actually is. The technical terminology for the above phenomena is "surfce refraction." Propagation by surface refraction is considered to be "ground wave" propagation consisting of the surface wave component.

3. TROPOSPHERIC REFRACTION--Just a few years ago, it was thought that the "4/3 radius" radio horizon was the useful limit of VHF transmission. Today we know that the troposphere exhibits a profound refractive effect upon VHF waves. A stratification of air density in this region of the atmosphere can produce bending of the VHF wave. This effect is termed "tropospheric refraction." The curvature of such a radio pattern is not constant, but tends to be greatest at areas of sharp discontinuity in the atmosphere. As a simplified analogy, the denser air at sea level is said to slow the wavefront just a little more than does the rarer upper air, imparting a downward curve to the wave travel. The effective radius range of VHF signals is thus extended well beyond the "4/3 radius" radio horizon in many instances. See figure 4.

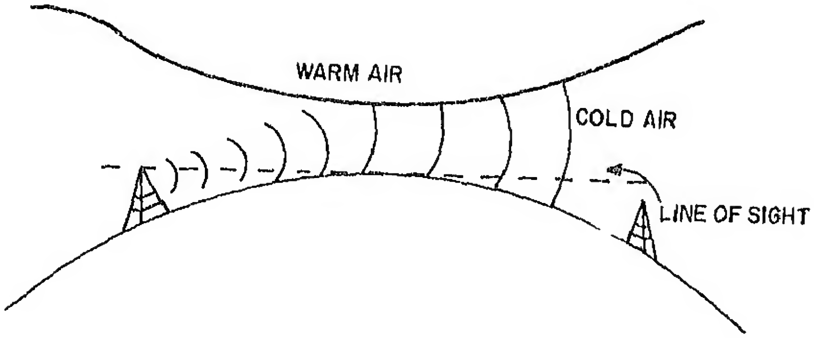


Figure 4

4. SUPER REFRACTION--In a windless, "standard" atmosphere, the temperature and water vapor content decrease steadily with altitude. In the course of average air movements and weather changes, the temperature and water vapor gradients may vary considerably from normal. Quite often a warm air mass will move in above a cooler mass, creating a "temperature inversion" such as shown in figure 4.

This change in air density will cause bending or refraction of the VHF/UHF wave. If the temperature rise exceeds 1.8° Celsius per 100 feet of altitude, the refractive effect will be just enough to cause the signal to follow the curvature of the earth. However, it should be noted that it is very unusual for the temperature gradient to reach this figure, and the condition is not common. Instead, it is the sharp drop in water vapor content which accompanies temperature inversions that is responsible for most cases of VHF/UHF wave bending. When the decrease in water vapor exceeds a figure of 0.5 gram per kilogram per 100 feet of altitude, the wave front will follow the curvature of the earth and long transmission paths may be covered with very little signal attenuation. The technical term that describes the bending of refractive effect caused by temperature inversion is "super refraction."

Temperature inversions occur most frequently along coastal areas bordering large bodies of water. This is a result of natural on-shore movement of cool, humid air shortly after sunset when the ground air cools more quickly than the upper air layers. The same action may take place in the mornings when the rising sun warms the upper air first. These conditions are most likely to take place during the warmer months of the year.

Probably the most spectacular temperature inversions take place at an altitude of several thousand feet. These inversions are created at the junction of large continental air masses which are always moving across the earth's surface.

Accurate prediction of super refraction is difficult, if not impossible, at least with present weather information.

5. FORWARD SCATTER--VHF propagation has consistently defied expected limitations. Until a few years ago, it was possible to explain occasional long-distance phenomena as resulting from super refraction, knife edge bending, or ionospheric skip. But with the advent of higher transmitter power levels, larger antenna systems, and more sensitive receiving equipment, it was found that VHF/UHF signals never fall off abruptly below the horizon. Instead, they travel on for surprising distances, and with only a gradual decrease in signal strength. Relatively high power is necessary to maintain a long-distance circuit, especially since the signal fluctuates rapidly over a range of many decibels. The outstanding characteristic of such a "beyond horizon" signal is that the average signal level is quite constant, regardless of weather or ionospheric conditions. As a matter of fact, it is possible to achieve a more reliable communication circuit with VHF/UHF at distances of up to about 1400 miles than is possible with any lower frequency. This new form of propagation is called "forward scatter," or simply "scatter," and is separated into two distinct types: tropospheric scatter and ionospheric scatter.

6. Tropospheric scatter is caused by random irregularities in the atmosphere which are apparently always present. The index of atmospheric refraction is changed sufficiently by these irregularities to cause faint signal illumination of the ground well beyond the horizon in much the same way that the overhead light beam of a searchlight can be seen from the ground, or the lights of a distant city can be seen as a glow from beyond the horizon. There is theoretically no limit to the possible range, although present techniques place the practical limit at about 500 miles for tropospheric scatter. Attenuation increases grdually with frequency, but rapidly with an increase in path length.

There are two types of signal fading encountered in scatter propagation. The first type is the rapid fade which is caused by multipath transmission through the atmosphere. The rate of fading increases as either frequency or distance is increased. At 150 MHz, multipath fading may drop the signal from maximum strength to minimum, and back to maximum in a matter of seconds.

The fast multipath fading will tend to reduce the allowable bandwidth of the communication circuit somewhat, since there may be several signal components arriving at slightly different times at any given segment of the multipath signal. However, indications are that serious difficulty will not be encountered with bandwidths less than 4 MHz, as used in TV video circuits.

The second type of fading is the slower type having a period of hours or even days. These slow changes in signal level are the result of variations in atmospheric refraction from day to night, and of humidity and temperature changes along the scatter path.

NOTETAKING SHEET 4.14.1N

RADIO WAVE PROPAGATION

REFERENCES:

1. Electronic Circuit Analysis, Vol. II, NAVAIR 000-80-T-79, pages 15-3 to 15-8, 15-21 to 15-23.

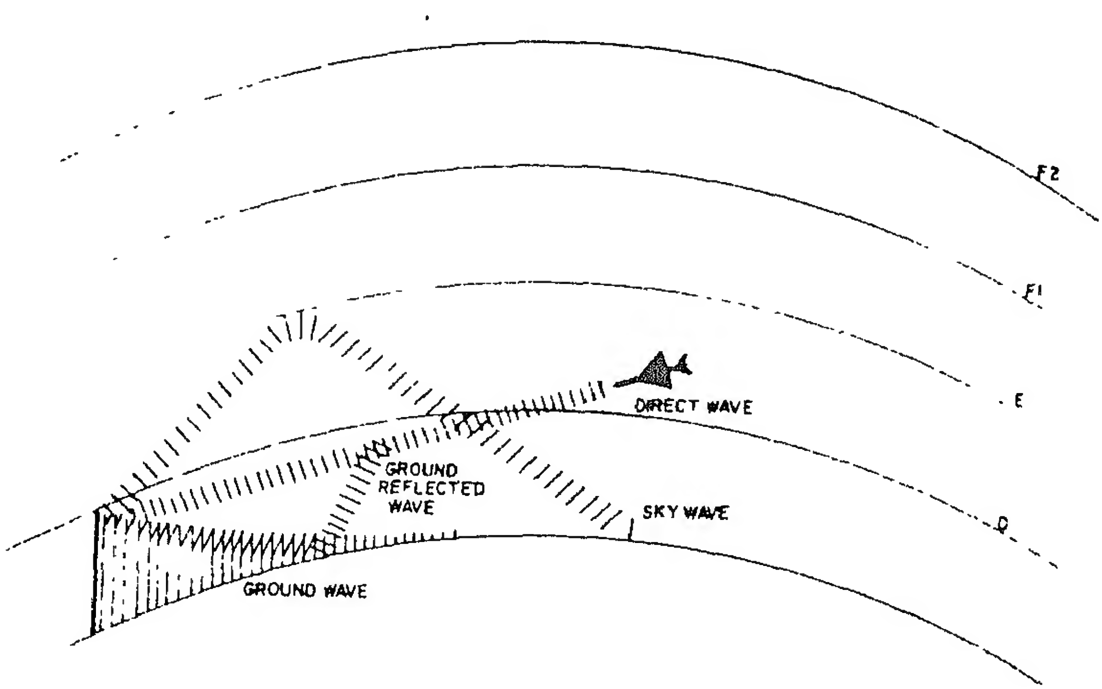
2. Antennas and Radio Propagation, Department of the Army, TM-11-666, Chapter 2.

NOTETAKING OUTLINE:

A. Radio Wave Propagation

   1. Definition

   2. Types of radio wave propagation



Wave Propagation

Figure 1

B. Media of Propagation

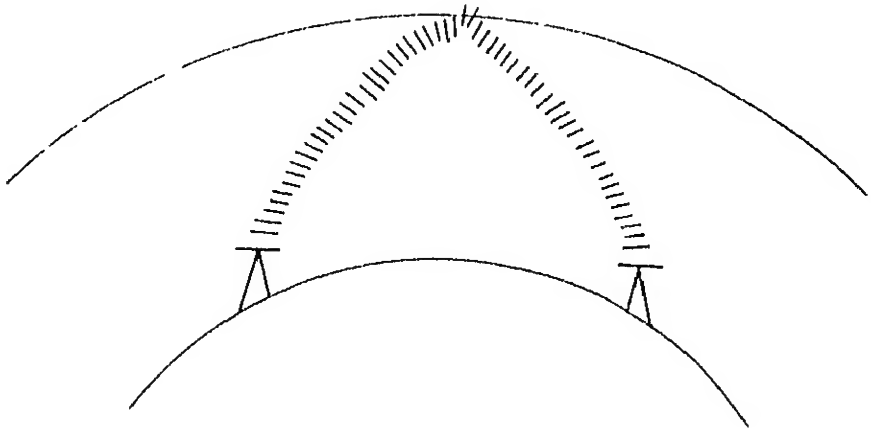
1. Earth's Surface

MATERIAL	CONDUCT-IVITY	DIELECTRIC CONSTANT
SEA WATER	GOOD	81
FRESH WATER	FAIR	80
WET SOIL	FAIR	20
FLAT LOAMY SOIL	FAIR	13
DRY & ROCKY OR DESERT	POOR	10
JUNGLE	UNUSUABLE	NOT CALCULABLE

Table of conductivity and Dielectric Constant

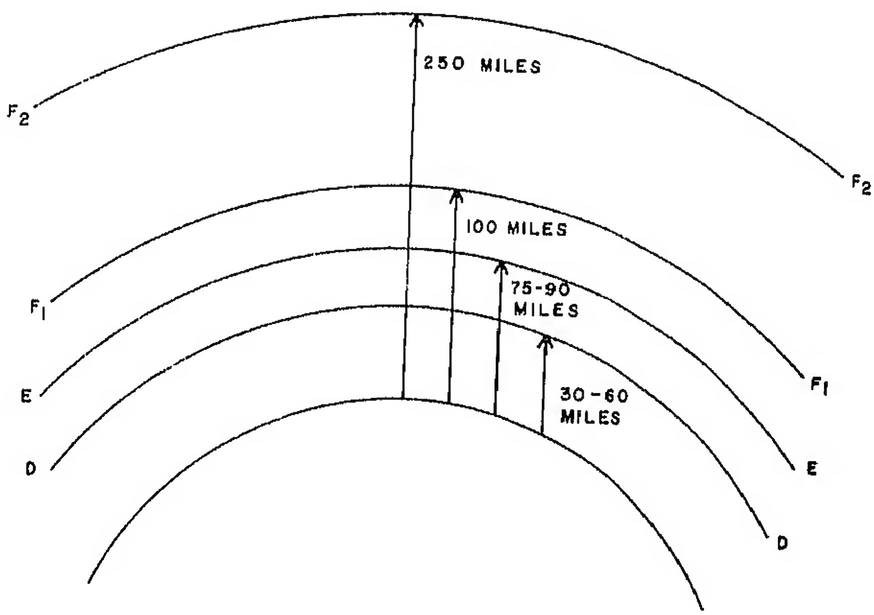
Figure 2

2. Ionosphere - up to 30 MHz



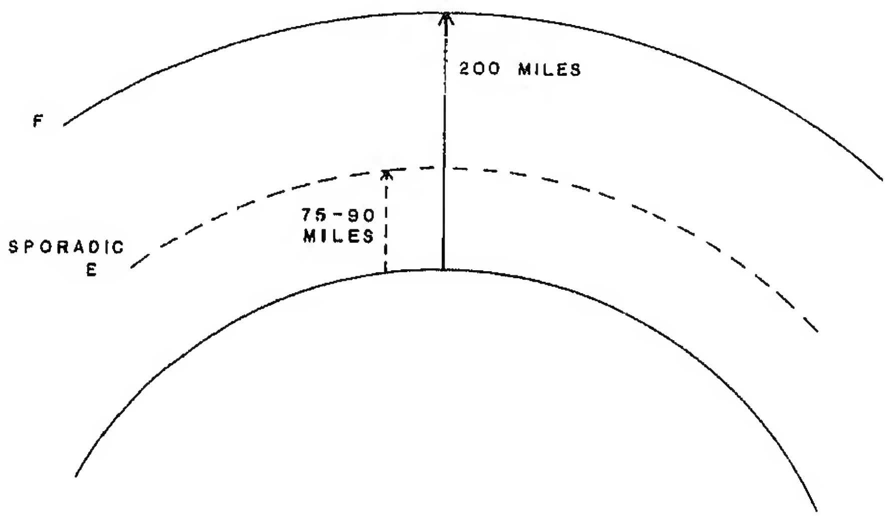
Refracted Wave

Figure 3



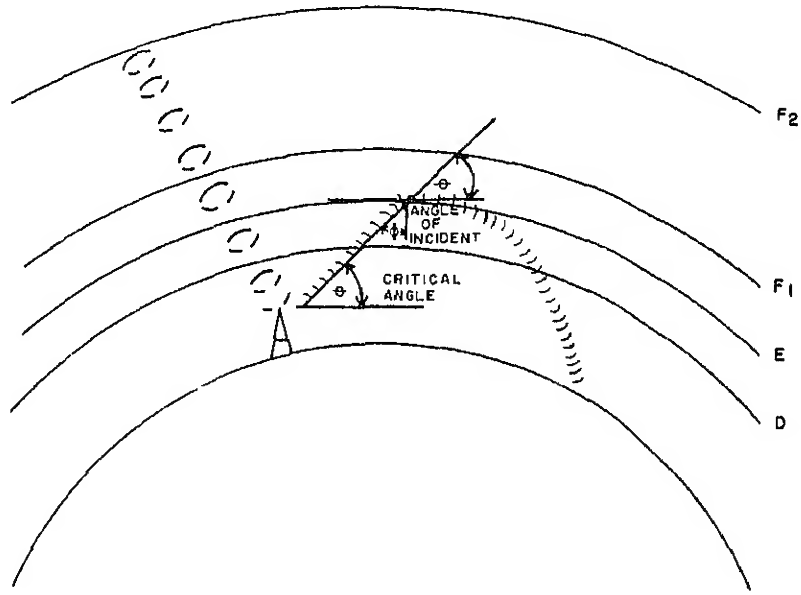
Ionosphere - Daytime

Figure 4



Ionosphere - Night Time

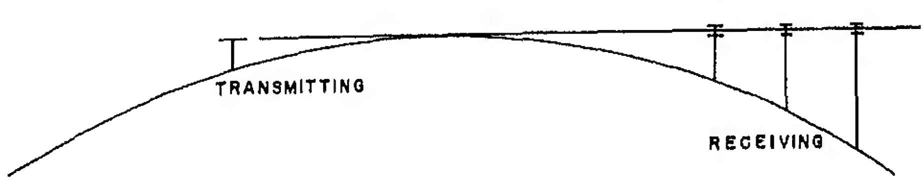
Figure 5



Critical Anlge and Frequency

Figure 6

3. Troposphere (lower atmosphere)



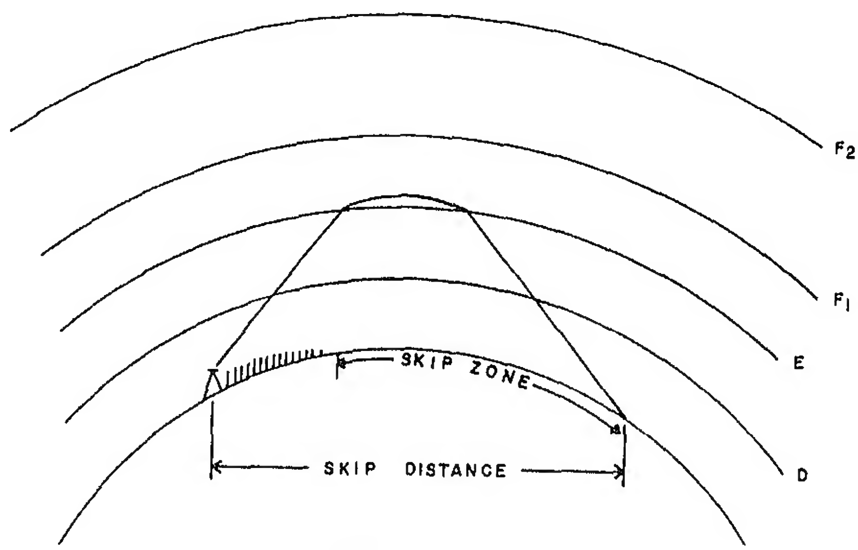
Line of Sight

Figure 7

C. Radio Wave Phenomenon

1. Skip distance

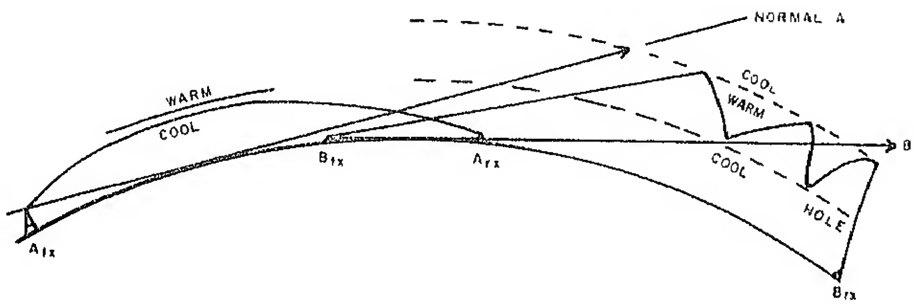
2. Skip zone



Skywave

Figure 8

3. Ducting



Ducting

Figure 9

FILM GUIDE 4.15.1F

STANDING WAVES ON TRANSMISSION LINES

INTRODUCTION

The purpose of this Film Guide is to provide you with guidance on what to look for in the film MN-1540-K, "Standing Waves on Transmission Lines." In addition, this guide is to be used in place of a notetaking sheet for the material covered by the film. It also contains an in-class assignment to ensure understanding of the material. The film will provide you with an introduction to the transmission line and demonstrate the effects and causes of standing waves. Upon completion of the film, the material covered will be reviewed.

POINTS TO LOOK FOR

1. The ill effect of the standing wave.

2. How standing waves are created.

3. Method of securing a matched condition.

4. Theory of how a line is charged progressively, section by section.

5. The amplitude of the standing wave of voltage curve at the open termination.

6. The amplitude of the standing wave of voltage at the shorted termination.

SHOW FILM-MN-1540-K," Standing Waves on Transmission Lines."

REVIEW QUESTIONS

1. In a transmission line operated with standing waves, an insulation breakdown is most likely to occur at a

   a. current maximum.

   b. current minimum.

   c. voltage maximum.

   d. voltage minimum.

2. Standing waves will result in a transmission line feeding an antenna if there is a mismatch between the

   a. load and the line.

   b. line and the transmitter.

   c. transmitter and the load.

3. Greatest transfer of energy between the source and the load will occur when there is a match between the load and the ________________.

4. When the transmission line is terminated with an open, the resultant standing wave of voltage will be maximum/minimum at the open termination.

5. When a transmission line is terminated by a short, the resultant standing wave of current will be maximum/minimum at the short.

6. Standing waves are the result of a mismatch between the load and the line and occur as a result of the incident voltage combining with the ________________ voltage.

7. A match between the load and the line will result in a standing wave ratio of 1:1 or a ________________ line.

FILM GUIDE 4.15.2F

TRANSMISSION LINE THEORY

INTRODUCTION

The purpose of this Film Guide is to provide you with guidance on what to look for in film 25362DN, "Transmission Line Theory." This guide is to be used in place of a notetaking sheet for the material covered in the film. There are review questions to ensure understanding. This film will provide you with introductory material about basic transmission lines. Upon completion, answer the review questions and they will be discussed in class.

Points to look for

1. The purpose of a transmisson line.

2. How wavelength varies with frequency.

3. What causes losses in transmission lines?

4. What determines the velocity at which energy travels in a transmission line?

5. What determines the characteristic impedance of a transmission line?

6. What is the phase relationship between the voltage and current leaving the source?

7. What type of circuit is represented by a voltage maximum, impedance maximum and current minimum?

8. What type of circuit is represented by a voltage minimum, impedance minimum and an current maximum?

Show film 25362DN, "Transmission Line Theory."

REVIEW QUESTIONS

1. What are the three major losses incurred in transmission lines?

    a. Copper, leakage and radiation.

    b. Heat, radiation and leakage.

    c. Capacitive, inductive and leakage.

    d. Capacitive, leakage and resistive.

2. How does the velocity of energy in a transmission line compare to the velocity in free space?

    a. Faster.

    b. Slower.

    c. The same.

    d. There is no relationship.

3. What causes the standing wave?

4. What are the voltage and current phase relationships in the standing wave?

    a. In phase.

    b. 180° out-of-phase.

    c. 90° out-of-phase.

INFORMATION SHEET 4.15.1I

TRANSMISSION LINE THEORY

INTRODUCTION

Basic transmission line theory includes the uses of transmission lines, types of transmission lines, and a comparision between the two-wire line and the coaxial line. This information sheet is provided for your use to address these areas and to provide you with a formula sheet applicable to transmission line theory.

REFERENCES

1. Electronic Circuit Analysis, Vol II, NAVAIR 000-80-79 pages 10-1 to 10-25.

2. Antennas and Radio Propagation, TM-11-666, pages 57-59.

3. Antennas, Philco Training Manual, Vol I, pages 53-72.

INFORMATION

Uses of Transmission Lines

A. Transmission lines are used to transfer electrical energy from a power source to a load with the least possible loss. The length of commercial power transmission lines is measured in miles, while the length of transmission lines used in radar and radio communication systems is measured in inches or centimeters. Yet, a line that is hundreds of miles long physically may be electrically shorter than a line that is a fraction of an inch long. Although these extreme types of transmission lines are vastly different in construction, their function is the same: to transfer electric energy from one point to another, with little or no loss.

B. In radio communication systems, transmission lines are used to transfer RF energy from a transmitter to an antenna or from an antenna to a receiver. Transmission lines are also used as: (1) circuit elements (capacitors or inductors); (2) impedance-matching devices; (3) metallic insulators; (4) filters and (5) devices for measuring frequency. Transmission line theory is closely related to antenna theory. Thus, you may consider antennas as transmission lines coupled to free space.

Types of Transmission Lines

A. TWO-WIRE TRANSMISSION LINES: Two-wire transmission lines are most commonly used with radio equipments that operate in the LF, MF, and MHF, VHF ranges (15 kHz to 200 MHz). There are

four types of two-wire transmission lines: (1) parallel open-wire lines; (2) twin-lead lines; (3) shielded two-wire lines; and (4) twisted two-wire lines. In the parallel open-wire line, two parallel conductors are held a fixed distance apart by means of insulating spacers. Parallel open-wire lines are widely used because of the simple construction, economy, and efficiency. For frequencies up to 14 MHz, the conductors are generally spaced from 2 to 6 inches apart. for use at frequencies higher than 14 MHz, the maximum spacing may be less than 2 inches.

In the twin-lead line, two stranded parallel wires are molded into a plastic insulating material, usually polyethylene. Twin-lead lines are more compact, lighter in weight, and more flexible than parallel open-wire lines.

In the shielded two-wire line, the two conductors are held a fixed distance apart by molding them into the insulating material. A copper braid is woven over the insulating material. A protective waterproof covering (usually made of vinylite) is placed over the copper braid. The copper braid generally is grounded, to minimize stray coupling and radiation losses.

B. COAXIAL TRANSMISSION LINE: Coaxial transmission lines (often called coaxial cables) are either flexible or rigid. In both types of coaxial lines, one conductor is located inside the other. The flexible coaxial line has a solid-wire or stranded-wire inner conductor, surrounded throughout its length by molded insulation. Copper braid woven over the molded insulation, serves as the outer conductor. A protective vinylite covering is placed over the copper braid. The rigid coaxial line consists of a hollow cylinder (outer conductor) with a solid rod (inner conductor) running through the center of the cable. The inner conductor is held in position by insulating spacers.

In a coaxial line, the transmitted energy is confined to the space between the inner conductor and the inner wall of the outer conductor. The outer conductor provides a perfect shield. Thus, no electric or magnetic field extends outside the outer conductor. A rigid coaxial line is usually filled with dry compressed air or nitrogen to prevent the condensation of moisture inside the line. Condensation of moisture decreases the electrical resistance of the insulating spacers, and thus increases the flow of leadkage current across the spacers. Pressurization is especially important in coaxial lines that carry high peak voltages. Very high and ultra-high frequencies within flexible coaxial lines have much higher losses than rigid coaxial lines. Thus, flexible coaxial lines are used primarily over short distances. Coaxial lines are widely used in VHF and UHF radio equipment.

Comparison Between Two-Wire Line and Coaxial Line

OPEN-WIRE LINE		COAXIAL CABLE (RG-8A/U)	
Velocity Constant	0.975	Velocity Constant	0.66
Attenuation in dB/100'		Attenuation in dB/100'	
4 MHz	0.03	4 MHz	0.30
7 MHz	0.05	7 MHz	0.45
14 MHz	0.07	14 MHz	0.66
28 MHz	0.1	28 MHz	0.98
50 MHz	0.13	50 MHz	1.35
144 MHz	0.25	144 MHz	2.5

Attenuation characteristics of coaxial cable vary depending upon the type of dielectric used. The above figures for RG-8A/U are based on the use of solid polyethylene for the center dielectric. Using polyethylene foam will reduce the attenuation in dB/100' at 144 MHz from 2.5 to 1.18, a considerable improvement.

Transmission Lines

$$Z_o = \frac{E_{applied}}{I_{flowing}} = \frac{E_{inc}}{I_{inc}}$$

$$I_{ref} = \Gamma I_{nc}$$

$$Z_o = \sqrt{L/C}$$

$$SWR = \frac{R_L}{Z_o} \text{ or } \frac{Z_o}{R_L}$$

$$Z_o = \frac{276}{\sqrt{K}} \log \frac{a}{b}$$

$$SWR = \frac{E_{max}}{E_{min}} = \frac{I_{max}}{I_{min}}$$

$$Z_o = \frac{138}{\sqrt{K}} \log \frac{a}{b}$$

$$ZSWR = (SWR)^2 = \frac{Z_{max}}{Z_{min}}$$

V_L is velocity of light in space. (300,000,000 m/s)

$$Z_{max} = \frac{E_{max}}{I_{min}}$$

V_G is velocity in conductor

$$Z_{min} = \frac{E_{min}}{I_{max}}$$

$$\lambda = \frac{\text{Velocity}}{\text{Frequency}}$$

$$E_{min} = E_{inc} - E_{ref}$$

$$E_{max} = E_{inc} + E_{ref}$$

$$\lambda(\text{meters}) = \frac{300}{f(\text{MHz})}$$

$$\lambda g = \frac{300}{f(\text{MHz})} V_K$$

$$\Gamma = \frac{R_L - Z_o}{R_L + Z_o} = \frac{SWR - 1}{SWR + 1}$$

$$E_{ref} = \Gamma E_{inc}$$

$$P_{dissip} = E_{load} I_{load}$$

$$T = N\sqrt{LC}$$

$$\frac{Z_{max}}{Z_o} = \frac{Z_o}{Z_{min}}$$

$$Z_{max} = \frac{{Z_o}^2}{Z_{min}}$$

$$Einc = \frac{E_{max} + E_{min}}{2}$$

$$I_{min} = I_{inc} - I_{ref}$$

$$I_{max} = I_{inc} + I_{ref}$$

$$P_{inc} = E_{inc} I_{inc} = \frac{(E_{inc})^2}{Z_o}$$

$$P_{ref} = E_{ref} I_{ref} = \Gamma^2 P_{inc}$$

$$Z_Q = \sqrt{Z_a Z_o}$$

Radio Wave Propagation

$\text{Range (miles)} = 1.41 \left(\sqrt{h_t} + \sqrt{h_r}\right)$ h is in feet

Delay Lines and PFNs

$$TD = N\sqrt{LC}$$

$$PW = 2TD$$

$$F_{co} = \frac{1}{\pi\sqrt{LC}}$$

NOTETAKING SHEET 4.15.1N

TRANSMISSION LINE THEORY

REFERENCES:

1. Electronic Circuit Analysis, Vol II, NAVAIR 000-80-T-79, pages 10-1 to 10-25.

2. Antennas and Radio Propagation, TM 11-666, pages 57-79.

3. Antennas, Philco Training Manual Vol I, pages 53-72.

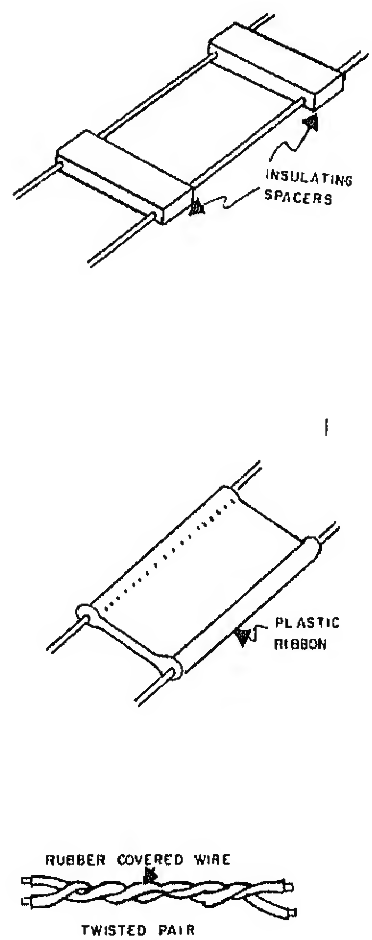
NOTETAKING OUTLINE

A. Types of Lines

1. Open two-wire line

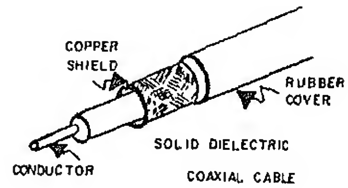
2. Twinex line

3. Twisted pair line



Types of Transmission Lines
Figure 1

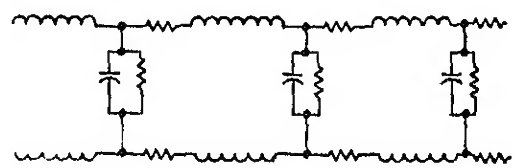
4. Coaxial line (flexible)



B. Losses Incurred in Lines

1. General information

2. Copper losses (I^2R)



Copper Losses
Figure 2

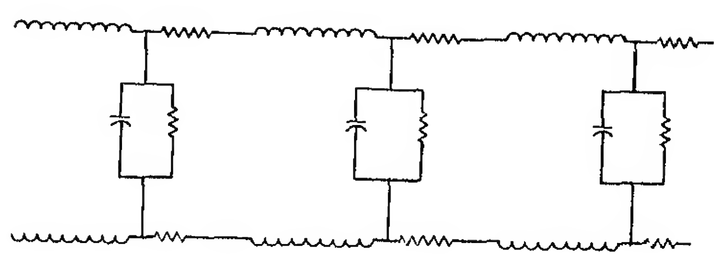
3. Dielectric losses

4. Radiation losses

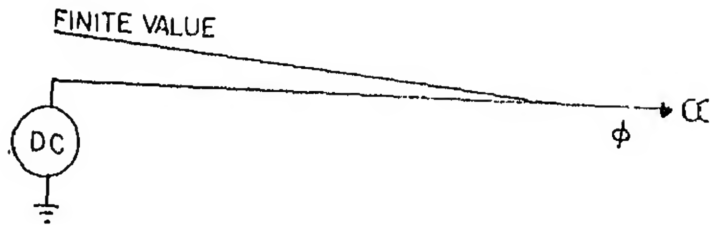
5. Losses in general

6. Impedance matching

C. Characteristic Impedance



Transmission Line Characteristics
Figure 3



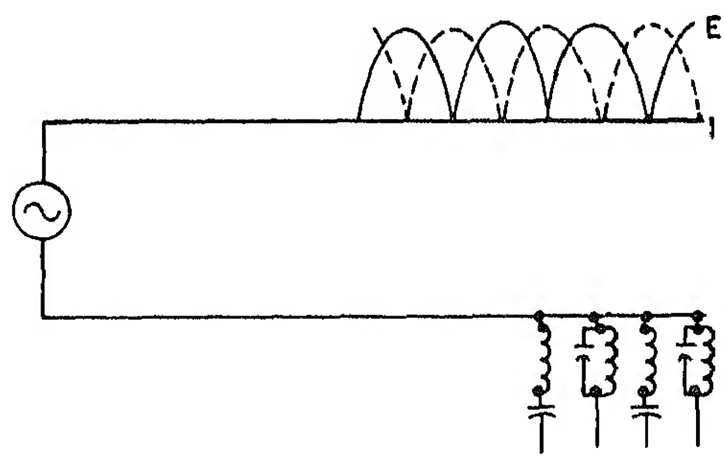
d.c. Voltage Applied

Figure 4

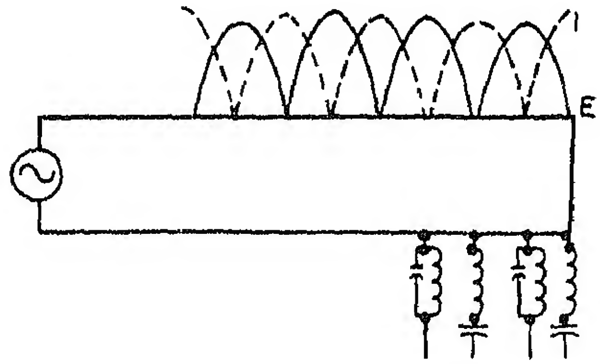
Characteristic Impedance
Figure 5

D. Velocity Constant

E. Reflections



Open Line
Figure 6



Shorted Line

Figure 7

F. Coefficient of Reflection (Γ)

G. Standing-Wave Ratio (SWR)

NOTETAKING SHEET 4.16.1N

USES OF TRANSMISSON LINES

REFERENCES:

1. Electronic Circuit Analysis, Vol. II, NAVAIR 000-80-T-79, pages 10-1 to 10-25.

2. Antennas and Radio Propagation, TM-11-666, pges 57-79.

3. Antennas, Philco Training Manual, Vol. II, pages 53-72.

NOTETAKING OUTLINE:

A. Feed Lines (Transmission Lines)

    1. Primary purpose

    2. Transmission line matching

    3. Tuned transmission lines

4. Half-wave antennas

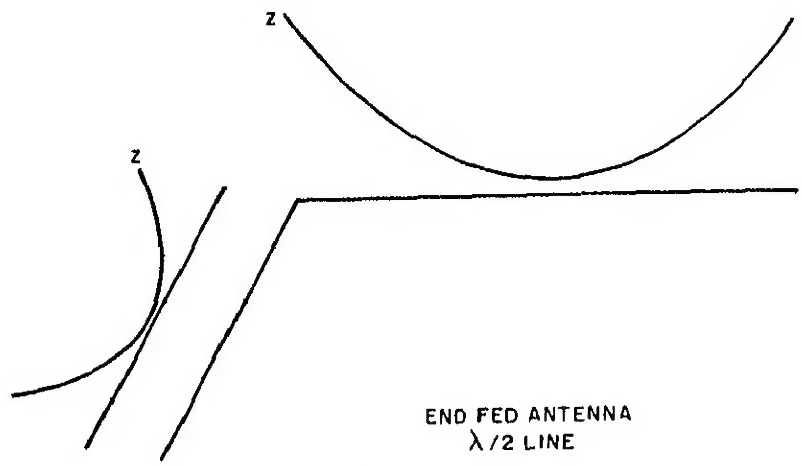


Figure 1

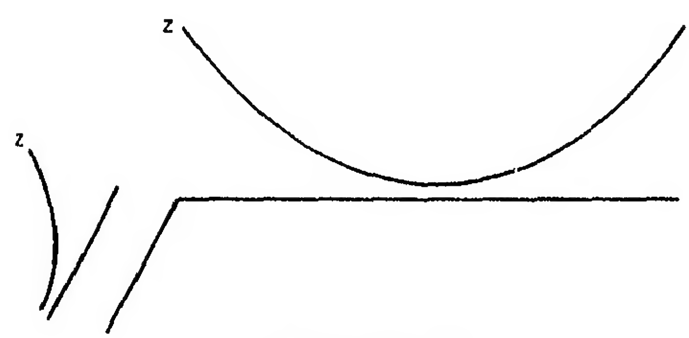
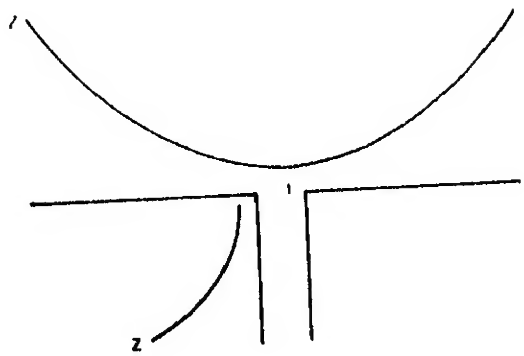
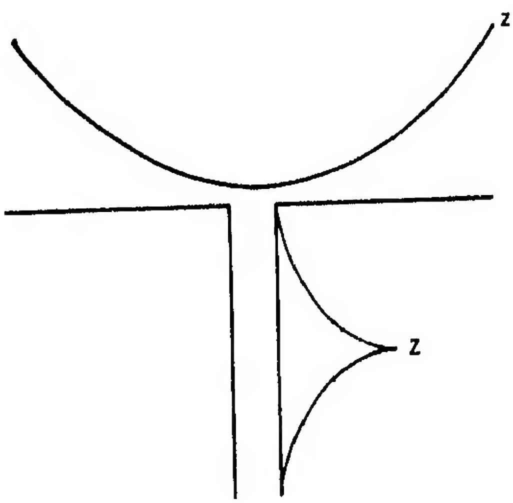


Figure 2



CENTER FED ANTENNA
λ/4 LINE

Figure 3



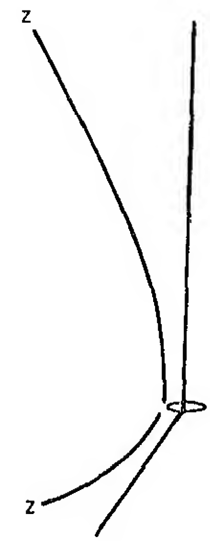
CENTER FED ANTENNA
λ/2 LINE

Figure 4

5. Quarters-wave antennas

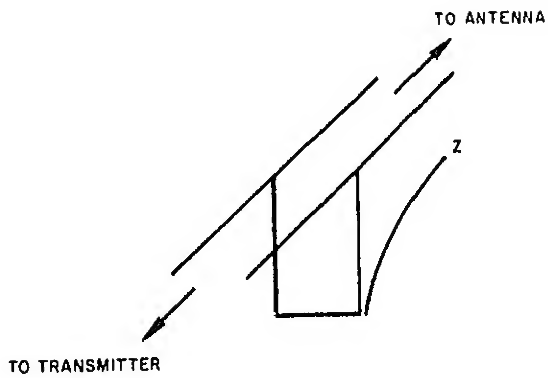
B. Stubs

1. Quarter-wave stub



BASE FED $\lambda/4$ ANTENNA
$\lambda/4$ LINE
Figure 5

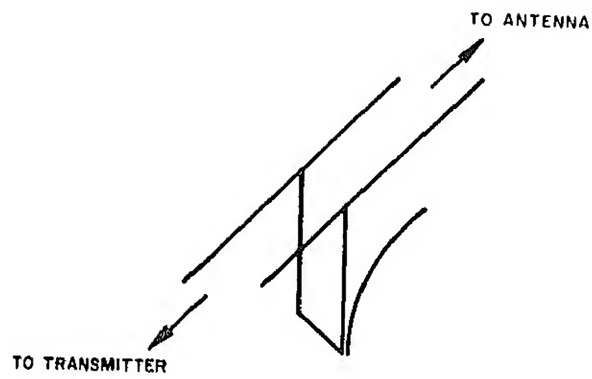
2. Stub uses in electronics



λ/4 SHORTED STUB INSULATOR

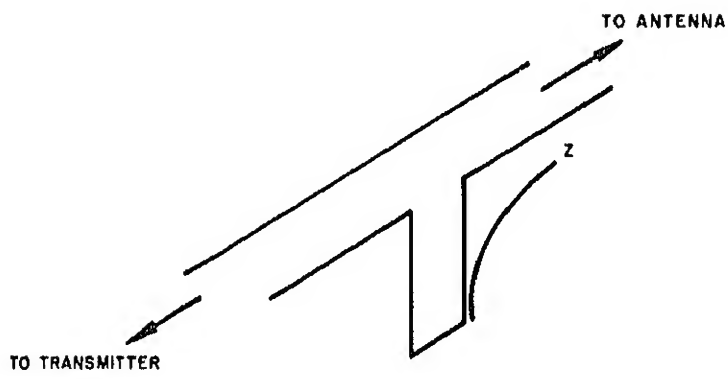
Figure 6

a. Filters



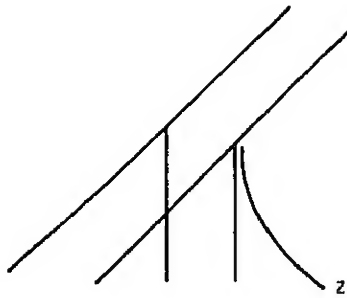
λ/4 SHORTED STUB
PARALLEL FILTER

Figure 7



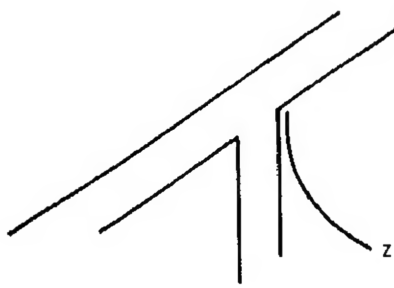
λ/4 SHORTED STUB
SERIES FILTER

Figure 8



λ/4 OPEN STUB
PARALLFL FILTER

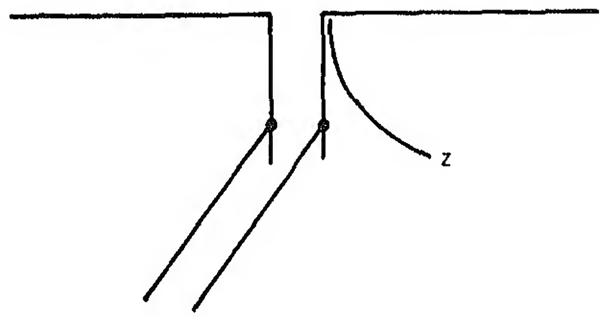
Figure 9



λ/4 OPEN STUB
SERIES FILTER

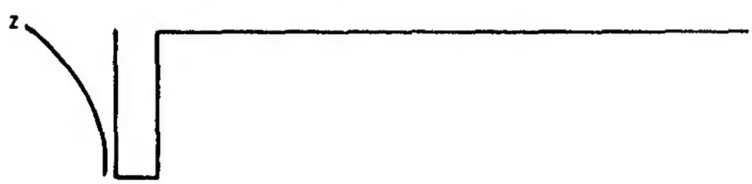
Figure 10

b. Impedance matching



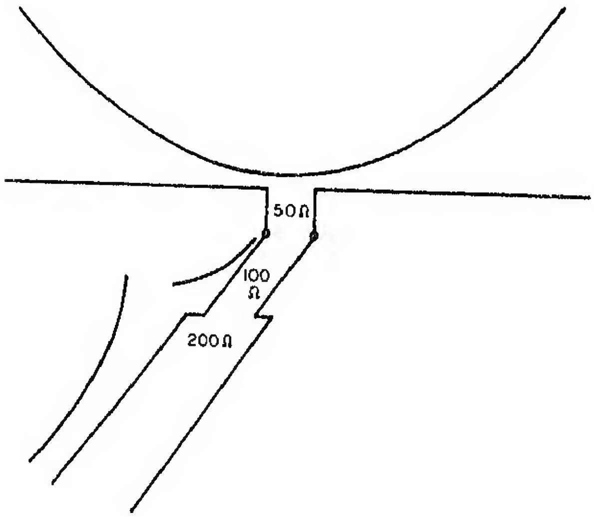
λ/4 OPEN STUB
IMPEDANCE MATCHING

Figure 11



λ/4 SHORTED STUB
IMPEDANCE MATCHING

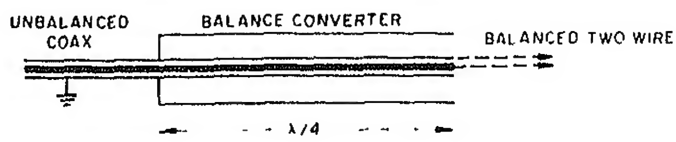
Figure 12



Q BAR λ/4
IMPEDANCE MATCHING
Figure 13

C. Other matching devices

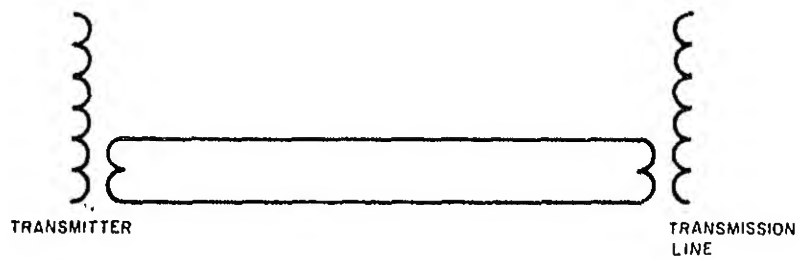
1. Balun



BAZOOKA

Figure 14

2. Link coupling



LINK COUPLING

Figure 15

FILM GUIDE 4.17.1F

RADIO ANTENNA FUNDAMENTALS, PART I

\TRODUCTION

ıe purpose of this Film Guide is to provide you with guidance on ıat to look for in film MN-9329A, "Radio Antenna Fundamentals, ırt 1". In addition, this guide is to be used in place of a ɔtetaking sheet for the material covered in the film. It also ɔntains an in-class assignment to ensure understanding of the ıterial. The film will provide you with introductory material to ɾansmission lines, basic antennas, typical antenna circuits and ırious applications of antennas. Upon completion of the film, ıe material will be reviewed.

ɔints to look for

- How a transmission line is progressively charged.
- Formation of standing waves on a transmission line.
- Characteristics of a transmission line with an open termination.
- Characteristics of a transmission line terminated in a short.
- Uses of a quarter-wave shorted stub.
- Methods of matching an antenna to a transmission line.
- Characteristics of a Marconi antenna.

ıow film--MV-9329A, "Radio Antenna Fundamentals, Part One".

ɜview questions

- How far down a two-wavelength transmission line will a sine wave travel if the generator is cut off after one sine wave has been produced?

___a. One wavelength.
___b. One-half wavelength.
___c. The entire length of the line.
___d. One-quarter wavelength.

How many sine waves will be produced by a generator before the first sine wave is felt at the termination of a four-wavelength transmission line?

____a. One.
____b. Two.
____c. Three.
____d. Four.

3. What is the amplitude of the voltage standing wave at an open termination?

____a. Maximum.
____b. Minimum.
____c. Same as incident voltage.
____d. Same as reflected voltage.

4. What type of circuit appears at the quarter-wave point back from an open termination?

____a. Parallel.
____b. Series.
____c. Capacitive.
____d. Inductive.

5. What is the amplitude of the current standing wave at a shorted termination?

____a. Same as incident current.
____b. Same as reflected current.
____c. Minimum.
____d. Maximum.

6. Which of the following methods can be used to match impedance of an antenna and a transmission line?

____a. Quarter-wave shorted stub.
____b. Delta match.
____c. Impedance transformer.
____d. Using a 300-ohm line to center-feed a half-wave point dipole.

7. What type of circuit appears at the half-wave point back from a shorted termination?

____a. Series.
____b. Capacitive.
____c. Inductive.
____d. Parallel.

8. A quarter-wave shorted stub can be used to replace which of the following circuits?

____a. Parallel-resonant circuit at low frequencies.
____b. Parallel-resonant circuit at high frequencies.
____c. Series-resonant circuit at low frequencies.
____d. Series-resonant circuit at high frequencies.

THEORY OF ANTENNAS

'RODUCTION

antennas have certain basic properties that can be easily ined. Knowing the properties of radiation patterns, beamwidth, arization, gain, impedance, bandwidth and radiation resistance essential for understanding the theory of any aircraft antenna.

ERENCES

Electronics Circuit Analysis, Vol. II, NAVAIR 00-80-T-79, pages 13-1 to 13-28.

Antennas and Radio Propagation, TM 11-666, pages 54-67, 89-114, 118-126.

Antennas, Philco-Ford Training Manual, AN 374A, pages 36-51, 100-110.

ORMATION

Radiation Patterns

a. The beamwidth of a radiation pattern is the angular width between the 3-dB (half-power) points of the main lobe (in respect to the lobe's maximum power point.)

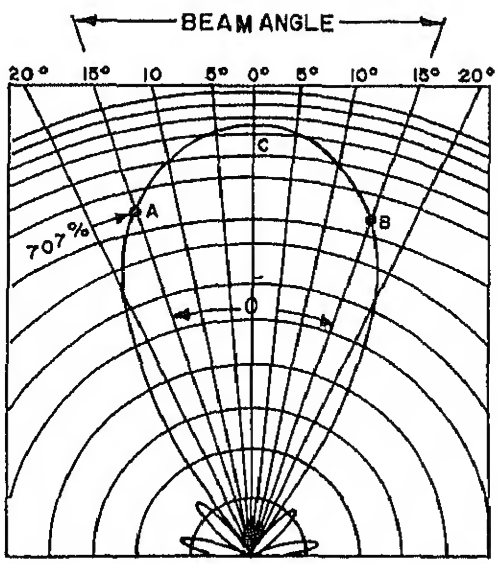


Figure 1

In figure 1, the half-power points are the points where the electric field strength (volts per meter) is 0.707 as great as maximum.

b. An omnidirectional pattern is used where all directions of a angle plane need to be covered equally well. This is normally accomplished in a horizontal plane, with the vertical plane having some directivity.

c. The pencil-beam pattern is a highly directional circular beam. This concentrated unidirectional beam yields maximum gain.

d. The fan-beam pattern is an elliptically shaped, directional beam with the beamwidth in one plane greater than in its respective perpendicular plane.

e. The shaped-beam pattern is when the pattern in one of the principal planes has a special type of coverage.

f. The cardioid (heart-shaped) pattern is used for direction finding purposes.

g. Factors that primarily determine the size and shape of an antenna's radiation pattern for a particular frequency are: size and shape of the radiating element and any parasitic elements: angular relationship and distance to parasitic elements to a ground or to any other reflecting surfaces.

2. Polarization

a. The directional component of the electric flux lines leaving an antenna will determine its polarization. Therefore, an electrical half-wavelength dipole antenna, which radiates or intercepts effectively the electric flux lines directly parallel to its axis, will be polarized in the same plane as its axis. This is called linear polarization.

b. Circular polarization can be produced by two perpendicular linearly polarized fields with a 90-degree phase differential.

3. Gain

a. Antenna gain is commonly referred to as a figure-of-merit.

b. The gain of an antenna is usually defined as the ratio of its maximum radiation intensity (field strength) in a given direction to that of a reference antenna with the same input power. The reference antenna will be specified, usually being a half-wave dipole or an isotropic radiator.

4. Impedance

   a. The input impedance of an antenna directly affects the energy transfer efficiency to or from the antenna. Therefore, each element and component of the antenna system and transmission line system must have favorable impedance properties for all frequencies of operation.

   b. Theoretical impedance values greatly shorten the "hit-and-miss" procedures which are often used when matching impedances.

5. Bandwidth

   a. An antenna must meet certain specifications within its intended band of frequencies. As an example, gain or impedance may determine its low frequency limits and a change of the radiation pattern may limit its upper frequency limit.

   b. The bandwidth of an antenna is closely related to its equivalent Q. The lower the Q, the greater the bandwidth.

6. Radiation Resistance

   a. This is a theoretical resistance, which will consume the same amount of power as is actually radiated from an antenna. The resistance is inserted in series with the antenna, usually at the point of its maximum current.

   b. The formula $R_{rad} = \frac{P_{rad}}{I_{max}^2}$ can be used as a memory aid to recall the definition of radiation resistance.

   c. A resonant half-wave antenna, remote from earth, has a radiation resistance of about 73 ohms.

   d. The total resistance component of antenna impedance is the sum of R_{loss} and R_{rad}.

   e. The efficiency of an antenna can be described as the formula of $Eff = \frac{R_{rad}}{R_{rad} + R_{loss}}$. Higher frequency antennas generally have higher efficiencies.

7. Antenna Length

   a. Because the velocity of RF energy differs in a conductor as compared to free space, the electrical and physical lengths of the antenna must also differ.

b. Factors affecting length

(1) The material or conductor having a dielectric constant greater than one (assuming the dielectric constant of free space is approximately 1) retards electromagnetic wave travel.

(2) As the circumference of the antenna increases, the capacitance increases, which decreases the velocity as seen by the use of the following formulas.

$$\text{Time} = \sqrt{LC} \qquad \text{Velocity} = \frac{\text{Distance}}{\text{Time}} \qquad \lambda = \frac{\text{Velocity}}{\text{Frequency}}$$

(3) Nearby objects of metal or dielectric material create stray capacitance which affects the velocity.

(a) The change in velocity caused by stray capacitance is called end-effect, because the ends of the antenna are made farther apart electrically than they are physically.

(b) To counteract this, the physical length is about 5 to 6 percent shorter than the electrical length.

NOTETAKING SHEET 4.17.1N

THEORY OF ANTENNAS

REFERENCES:

1. Electronics Circuit Analysis, Vol. II, NAVAIR 00-80-T-79, pages 13-1 to 13-18.

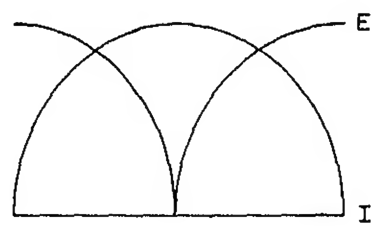
2. Antennas and Radio Propagation, TM 11-666, pages 54-67, 89-114, 118-126.

3. Antennas, Philco-Ford Training Manual, AN374A, pages 36-51, 100-110.

NOTETAKING OUTLINE:

A. Basic Antennas

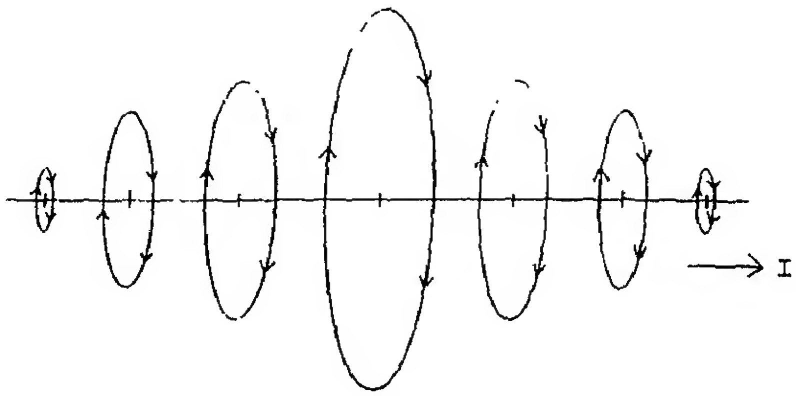
    1. Antenna



BASIC HALF-WAVE ANTENNA

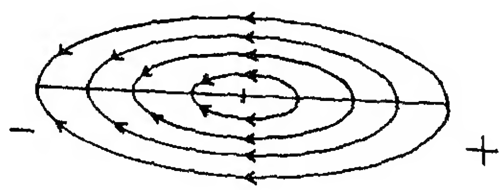
Figure 1

2. Electrical Properties



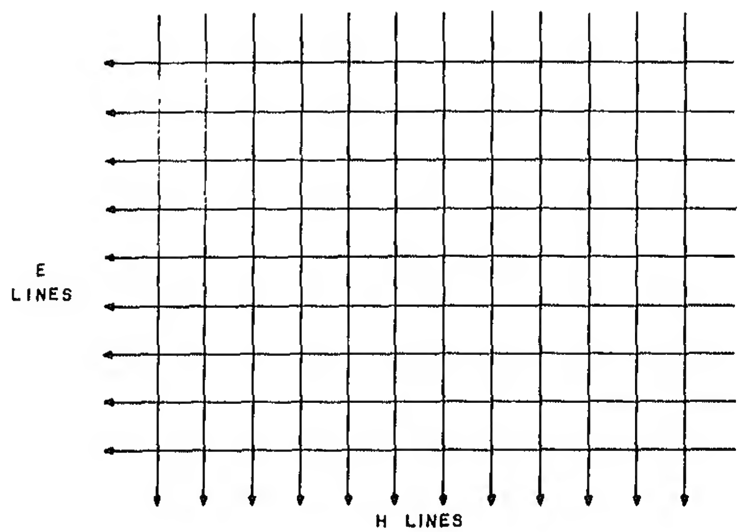
MAGNETIC LINES OF FORCE

Figure 2



ELECTROSTATIC LINES OF FORCE

Figure 3

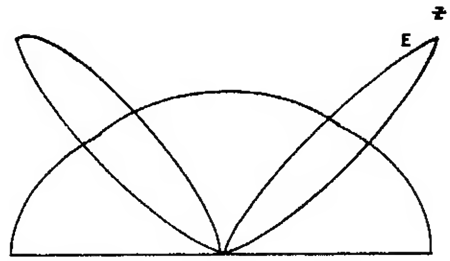


ELECTROMAGNETIC WAVE FRONT
AT A DISTANCE FROM THE ANTENNA

Figure 4

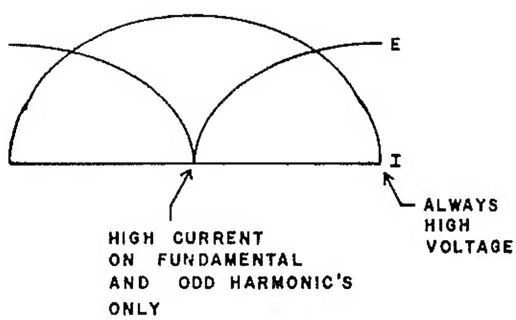
B. Operation of Antennas

1. Standing waves



STANDING WAVES
HALFWAVE ANTENNA

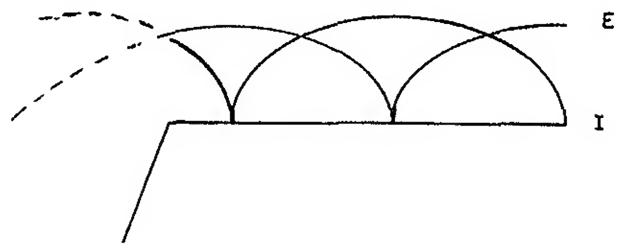
Figure 5



STANDING WAVES

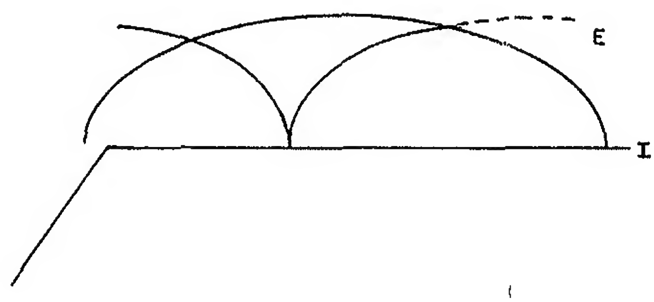
Figure 6

2. Off resonance



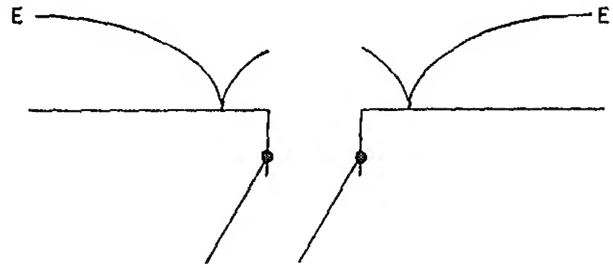
END FED
ABOVE RESONANCE

Figure 7



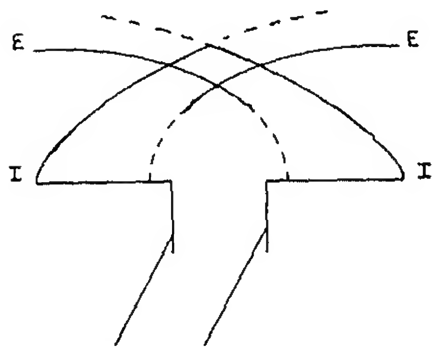
END FED
BELOW RESONANCE

Figure 8



CENTER FED
ABOVE RESONANCE

Figure 9

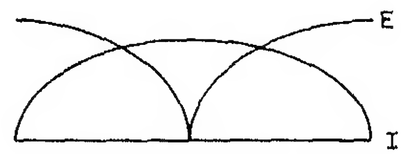


CENTER FED
BELOW RESONANCE

Figure 10

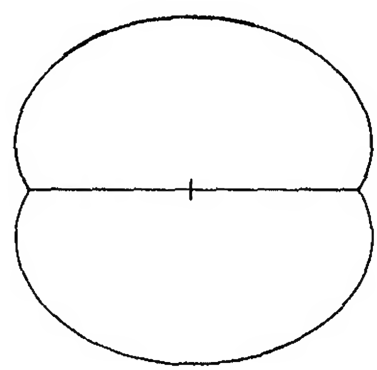
C. Antenna Types and Radiation Patterns

1. Fundamental antennas



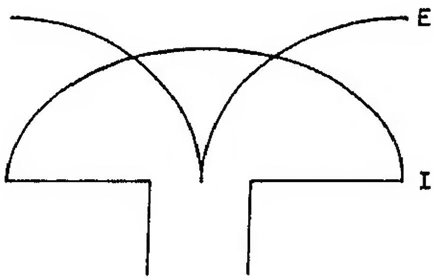
HALF-WAVE HERTZ

Figure 11



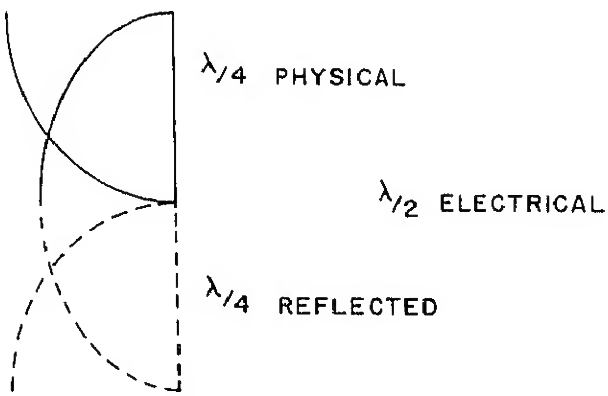
RADIATION PATTERN
HALF-WAVE
TOP VIEW

Figure 12



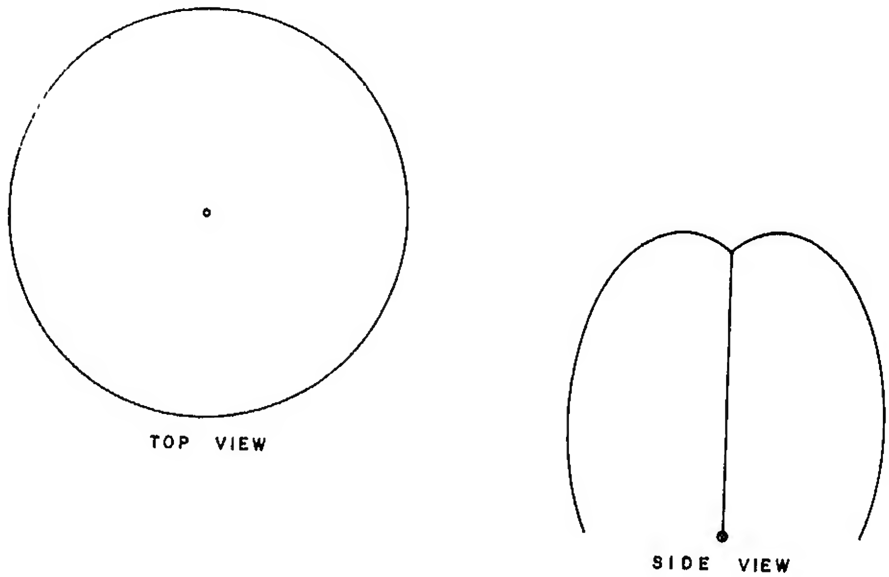
HALF-WAVE DIPOLE

Figure 13



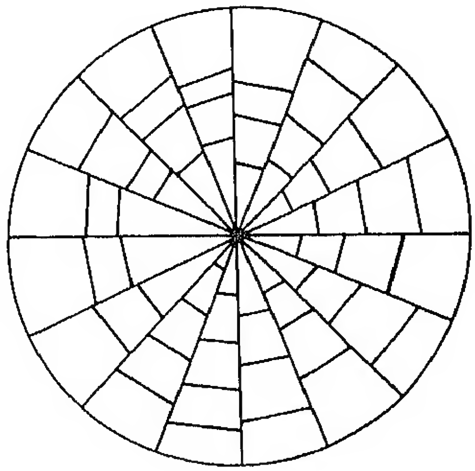
QUARTER-WAVE MARCONI

Figure 14



MARCONI ANTENNA
RADIATION PATTERN

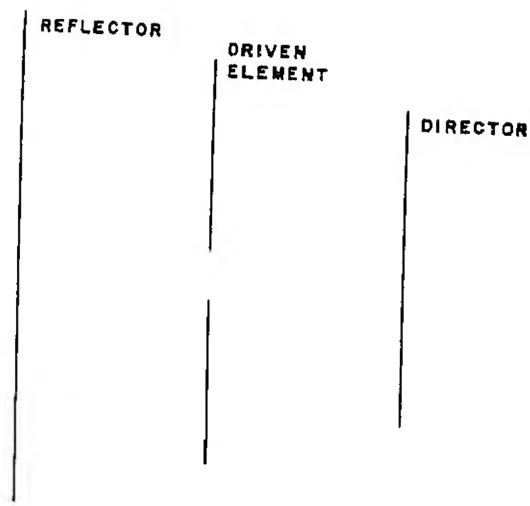
Figure 15



COUNTERPOISE

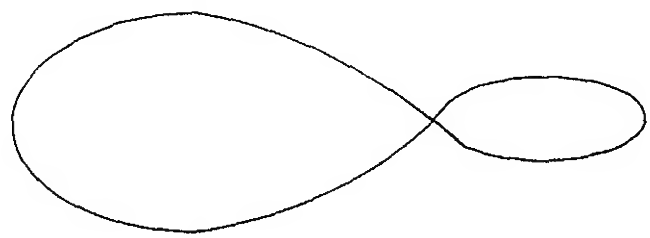
Figure 16

2. Other Antennas



DIRECTIONAL ARRAY

Figure 17

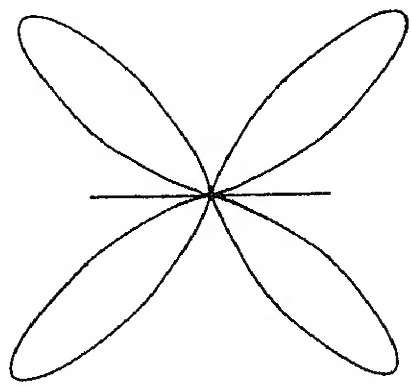


RADIATION PATTERN
UNIDIRECTIONAL ANTENNA

Figure 18

STANDING WAVES
LONG WIRE ANTENNA

Figure 19



RADIATION PATTERN
2 WAVE LENGTH ANTENNA

Figure 20